

Docket ID No. EPA-HQ-ORD-2011-0895  
Sean Kelly; March 8, 2012

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Comments on EPA Draft Research Report:  
Investigation of Ground Water Contamination  
near Pavillion, Wyoming

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**Public Comments By:**

Sean Kelly  
8073 South Adams Way  
Centennial, Colorado 80122-3603  
email: rockhound.sk@gmail.com

**Concerning:**

United States Environmental Protection Agency, Draft Research Report: Investigation of Ground Water Contamination near Pavillion, Wyoming. Released December 8, 2011

**Qualifications:**

**Education:**

BS, Geological Engineering, Colorado School of Mines, 1983

MS, Geological Engineering, Colorado School of Mines, 1988

**Certification and Licenses:**

American Association of Petroleum Geologists, Certified Petroleum Geologist No: 5599

State of Wyoming Licensed Professional Geologist No: PG-3105

State of Utah Licensed Professional Geologist No: 5558371-2250

State of Texas Licensed Professional Geologist No: 206

**Experience:**

I have 24 years of professional geologic and engineering experience studying and interpreting the movement of fluids in the subsurface. I have been recognized as an expert in the field of geology by various state agencies in Kansas, Louisiana, Oklahoma, Texas and Utah.

**Summary:**

I have reviewed the United States Environmental Protection Agency (EPA), Draft Research Report: Investigation of Ground Water Contamination near Pavillion, Wyoming (Draft Report). I respectfully request that the peer review panel gives serious consideration to the issues I raise and present in my comments that follow.

In my opinion, the overall investigation and resulting Draft Report contains several major technical flaws and deficiencies. As a result, the methodology and data presented in the draft report are entirely insufficient to reach the final far reaching conclusion "that inorganic and organic constituents associated with hydraulic fracturing have contaminated ground water at and below the depth used for domestic water supply" (Draft Report Pg. 39).

The word "associated" is particularly vague and troubling. The EPA has not taken the time to actually document the drilling and completion procedures and identify specifically the completion compounds

that were used to stimulate individual stages in producing gas wells in the immediate area of the two EPA monitor wells. Instead the EPA has grouped all known chemical compounds potentially "associated" with the hydraulic fracture stimulation process in the area into a single data set and attempted to identify the presence of any of these compounds or any possible natural breakdown products of any of these compounds in the EPA monitor wells without considering the locations (both areally and stratigraphically) where the chemical compounds were actually used. It is critically important to understand what compounds were used to hydraulically fracture stimulate specific wells and specific stratigraphic intervals since a concentrated contaminant plume will exist in the zone of injection with dispersed and diffused lower concentration areas vertically and laterally distant from the injection point EPA (2004).

The presence of hydrocarbons in the two deep EPA monitor wells is not surprising and should have been expected based on the geology of the area. The monitor wells were drilled into and screened in stratigraphic intervals which contain naturally occurring hydrocarbons in several offsetting wells. Proper due diligence and a review of publically available data on the part of the EPA prior to the siting and drilling of the two deep monitor wells would have clearly indicated the likelihood of encountering naturally occurring hydrocarbons in this area at the depths that the two deep EPA monitor wells were drilled to. The detected presence of methane, benzene, gasoline range organics, diesel range organics and BTEX are naturally occurring. To assume these compounds came exclusively from or a result of the hydraulic fracture stimulation process is a flawed conclusion.

The validity of the data used to reach the study's conclusions of alleged deep contamination is the most troubling aspect of the Draft Report. In my opinion the water sample data from the two EPA monitor wells is not stabilized and representative of the actual water present in the aquifers being tested. There are significant changes in the water chemistry from sampling stage III to sampling stage IV (many of the components analyzed have decreased by 50% or more). This is a clear indication that the two monitor wells and screened aquifers have not reached equilibrium and additional sampling is required to obtain what could be considered stabilized and representative ground water samples.

The sampling procedures do not meet the EPA's own established minimum guidelines for sampling and testing water wells.

The EPA interpretations rely almost entirely upon chemistry determinations. The geological interpretations presented in the Draft Report are woefully inadequate and hydrological interpretations are nonexistent.

I agree that the upper Wind River Formation aquifers do meet the EPA definition of an Underground Source of Drinking Water (USDW) under the United States Code of Federal Regulations, Title 40, Section 144.3. **However, the lower Wind River Formation aquifers below the lower laterally continuous intermediate seal (Sean Kelly Attachment No.3) in the Pavillion Field area should be exempt from the EPA definition of an USDW due to the quantities of naturally occurring hydrocarbons contained in these aquifers: United States Code of Federal Regulations, Title 40, Section 146.4.**

**Finally, the draft report does not emphasize enough the fact that a causal link was not established between the contamination detected in domestic sources of water and the alleged contamination from hydraulic fracturing claimed to be detected in the two deep EPA monitor wells (Draft Report Pg. 27). The EPA wasted considerable time, resources and capitol (\$1.7MM to date, according to the testimony of EPA Region 8 administrator Jim Martin before the House Subcommittee on Energy and Environment on February 1, 2012) with the hope of finally establishing a link to possible ground water**

contamination and hydraulic fracture stimulation activities by the oil and gas industry under the guise of investigating the "complaints by domestic well owners regarding objectionable taste and odor problems in well water" (Draft Report Pg. xi). Buried in the text on Pg. 27 of the Draft Report is the admission "the existing data at this time do not establish a definitive link between deep and shallow contamination of the aquifer".

**Attachments:**

Included with my public comments are **Attachments No. 1, Attachment No. 2 and Attachment No. 3:**

**Attachment No. 1** is a map showing the location of the wells I have evaluated in reviewing the Draft Report. Each well is identified by operator, well name and well number. Posted at each well location in red is the elevation of the informally named Wind River "B" Marker. Structural contours at a 20' contour interval are based on the elevation of the top of the informally named Wind River "B" Marker. The location of west to east cross section A – A' is shown in blue.

**Attachment No. 2** is stratigraphic correlation cross section A – A' which uses the informally named Wind River "B" Marker as a datum. This cross section is used to make well to well correlations defining the stratigraphy of the upper Wind River Formation.

Cross section wells are identified by operator, well name and well number posted above the well symbol. Depth in feet below the reference elevation is shown in the depth track. The depth scale is 1" = 200' and the wells are evenly spaced with no horizontal scale. Casing shoe points are indicated by black triangles, and perforated intervals are indicated by pink squares in the depth tracks. The screened intervals in the two EPA monitor wells are also indicated by pink squares in the depth tracks.

Resistivity curves are plotted in track 1 for each well on a linear scale of 75 to 0 ohm-m in a solid red curve. Gamma ray curves are also plotted in track 1 for each well with an available gamma ray log on a linear scale of 0 to 150 API units in a solid black curve. Where the gamma ray was run in a cased hole portion of the well, the data has been normalized so that 95% of the gamma ray data is greater than 45 API units and 5% of the gamma ray data is greater than 130 API units. The resistivity curves show good correlation to the gamma ray curves when plotted at these scales which provides confidence for correlating the resistivity curves provided for the two deep monitor wells to the logs from the producing gas wells in the area.

The gamma ray curve is shaded based on gamma ray values. Sandstone intervals are generally shaded from yellow to orange, and shale intervals are generally shaded from gray to black.

The correlations of the informally named Wind River stratigraphic tops are shown in red and green lines. Overall, there is good correlation of the upper Wind River stratigraphy along the span of cross section A – A'.

**Attachment No. 3** is structural cross section A – A' which utilizes a "triple-combo" log display. Cross section wells are identified by operator, well name and well number posted above the well symbol. Depth in feet below the reference elevation is shown in the depth track. The depth scale is 1" = 100' and the horizontal scale is 1" = 225'. Casing shoe depths are indicated by black triangles, and perforated intervals are indicated by pink squares in the depth track. The screened intervals in the two EPA monitor wells are also indicated by pink squares in the depth tracks.

The correlations of the informally named Wind River stratigraphic tops are shown in red and green lines, and are identical to the correlations shown in **Attachment No. 2**.

Gamma ray curves are plotted in track 1 for each well with an available gamma ray on a linear scale of 0 to 150 API units as a solid black curve. Where the gamma ray was run in a cased hole portion of the well, the data has been normalized so that 95% of the gamma ray data is greater than 45 API units and 5% of the gamma ray data is greater than 130 API units. The gamma ray curve is shaded based on gamma ray values. Sandstone intervals are generally shaded from yellow to orange, and shale intervals are generally shaded from gray to black.

A caliper log is also plotted in track 1 for each well with an available caliper on a linear scale of 4 to 14 inches as a solid black curve.

Resistivity curves are plotted in track 2 on a log scale of 2.0 to 200 ohm-m. The shallow resistivity curve is plotted as a black dotted curve, the medium resistivity curve is plotted as a black dashed curve and the deep resistivity is plotted as a solid red curve. Where the deep resistivity reading is greater than a 20 ohm-m it is shaded green.

Porosity curves are plotted in track 3 for each well with an available porosity log on a linear scale of 30% to 0%. Density porosity is plotted as a solid red curve, and neutron porosity is plotted as a black dashed curve. Density porosity is calculated using an assumed matrix density of 2.65 g/cc. Where the neutron porosity reads less than the density porosity (a condition known as "cross-over" or "gas effect") the cross-over is shaded red with a black stippled pattern.

Wind River Formation intervals which have been proven productive of natural gas through perforating and testing in gas productive wells are consistently identified by open hole log responses where the deep resistivity is greater than 20 ohm-m and the neutron-density porosity exhibits crossover or gas effect. All intervals which have these "natural gas pay parameters" of combined deep resistivity greater than 20 ohm-m and neutron-density crossover are highlighted by red shading between the neutron porosity curve and the right edge of track 3.

#### **Summary of Draft Report Major Technical Flaws:**

1. The two deep monitor wells were drilled into and screened in intervals containing naturally occurring hydrocarbons.
2. No records kept of fluid losses while drilling the two deep monitor wells.
3. Failure to identify the chemical nature of the portland cement used to cement the casing of the two EPA monitor wells and to fill the open hole below the Randall MW01 screened interval.
4. Very limited ground water sampling in the two deep monitor wells.
5. Insufficient water purge volumes prior to water sampling.
6. Invalid non-stabilized, non-representative ground water samples were used to reach the final Draft Report conclusions.
7. Laboratory errors, contamination questions and non-repeatable laboratory results.
8. No attempt to identify what was specifically used to hydraulically fracture stimulate wells in the vicinity of the monitor wells and how the completion procedures and locations compare to the screened intervals of the monitor wells (in terms of areal and stratigraphic extents).

#### **Summary of Draft Report Major Deficiencies:**

1. No easily discernible location maps.
2. Extremely poor records of operations and completions – illegible.
3. Release of monitor well open hole logs.

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4. Release of monitor well cement bond/variable density logs demonstrating mechanical isolation from shallow zones.
5. The EPA interpretations rely almost entirely upon chemistry determinations. The geological interpretations presented in the Draft Report are woefully inadequate and hydrological interpretations are nonexistent.
6. Lack of understanding of the natural variations in ground water both locally and regionally.
7. No chemical analysis of water produced by Pavillion Field gas production wells.
8. Failure to recognize that thermogenically derived natural gas can migrate vertically over time through natural buoyant processes without the presence of 1.) producing wellbores, 2.) "hydraulic fracture stimulation fluid excursion" or 3.) new fractures generated during the hydraulic fracture stimulation process (Draft Report Pg. 32)
9. Failure to recognize that cement bond/variable density logs run under non pressurized or "0 psi" conditions are unreliable and often pessimistic in evaluating actual cement effectiveness due to the presence of a microannulus.
10. Failure to thoroughly investigate potential causes of contamination other than oil and gas operations.
11. Failure to conduct a true scientific investigation based on the scientific method.

**Specific Comments on Draft Report Major Technical Flaws:**

1. The two deep EPA monitor wells (Randall MW01 and Locker MW02) were drilled into and screened in intervals known to contain naturally occurring hydrocarbons. The two deep monitor wells were drilled in an area of structural closure below the depths of laterally continuous seals (**Sean Kelly –Attachment No.1** and **Sean Kelly-Attachment No.3**). This is historically the most common industry method of exploration for commercial hydrocarbon deposits.

A review of publically available data prior to drilling two deep EPA monitor wells would have identified the presence of hydrocarbons in offset wells at and above the screened depths of the monitor wells. It should be expected that hydrocarbons are encountered in these monitor wells. The hydrocarbons are naturally occurring and not related to, or the result of oil and natural gas operations in the area. Naturally occurring hydrocarbons that were detected in the monitor wells and would also be expected to be present in hydrocarbon bearing intervals would include: methane, benzene, gasoline range organics, diesel range organics and BTEX.

The EPA's own review of open hole well logs in the Pavillion area identified the presence of shallow naturally occurring hydrocarbons at depths used for domestic water supplies (Draft Report Pg. 27). My very limited review of open hole logs (only eleven wells) identifies at least 42 Wind River Formation intervals with probable natural gas at depths less than 1,500' (**Sean Kelly-Attachment No.3**). There are at least 13 Wind River Formation intervals with probable natural gas at depths less than 800' (**Sean Kelly-Attachment No.3**) which is the depth the Draft Report identifies as the screened depth for the deepest domestic and stock wells in the area (Draft Report Pg. xi). I have identified Wind River intervals with probable hydrocarbons as shallow as 565-573' in the Encana Pavillion Fee 11-11B and 541-551' in the Tom Brown Pavillion Fee 41-10.

Shallower hydrocarbon bearing zones are also likely to be present but cannot be specifically identified through log analysis due to a lack of open hole logs or mud logs run in the surface hole portion of the gas producing wells.

The two deep monitor wells were screened in separate stratigraphic intervals. The Locker MW02 which is screened in a deeper aquifer has higher concentrations of naturally occurring hydrocarbons. This is consistent with a model of hydrocarbons naturally migrating up from thermally mature source rocks contained in deeper strata. The EPA's interpretation of upward migrating natural gas of a thermogenic origin as the source of the hydrocarbons identified in shallow strata is correct (Draft Report Pg. 29). The major flaw in the EPA interpretation is that the source for the hydrocarbons identified in the shallow strata is from a much deeper source than any of the producing gas wells drilled in Pavillion Field, is naturally occurring and is totally unrelated to oil and gas operations.

I agree that the upper Wind River Formation aquifers do meet the EPA definition of an Underground Source of Drinking Water (USDW) under the United States Code of Federal Regulations, Title 40, Section 144.3. **However, the lower Wind River Formation aquifers below the lower laterally continuous intermediate seal (Sean Kelly Attachment No.3) in the Pavillion Field area should be exempt from the EPA definition of USDW due to the quantities of naturally occurring hydrocarbons contained in these aquifers: United States Code of Federal Regulations, Title 40, Section 146.4. "Ground water contamination with constituents such as those found at Pavillion is typically infeasible or too expensive to remediate or restore (GAO 1989)" (Draft Report Pg. 39).**

Finally, if the primary purpose of this EPA ground water investigation was to investigate "complaints by domestic well owners regarding objectionable taste and odor problems in well water" (Draft Report Pg. xi), then why were the two EPA monitor wells drilled to depths well below where the vast majority of domestic water wells in the area produce water? The EPA had already determined that pits used for storage/disposal of drilling wastes, produced water and flowback fluids were the most likely source of shallow ground water contamination which is the primary source of domestic water in the area of investigation (Draft Report Pg. 17). **This raises serious questions about the actual EPA motives for performing this study and what the EPA was actually attempting to find and arguably pre-determined to find.**

A much more meaningful and beneficial study to the residents of the Pavillion area would have been for the EPA to analyze the potential aquifer sandstones located at depths of 206-230' and 372-396' in the Randall MW01 monitor well and at depths of 248-256', 266-287', 400-420' and 489-512' in the Locker MW02 monitor well. These are potential aquifers that are much more likely to be utilized by the local residents for domestic water.

2. No records kept of fluid losses while drilling the two deep monitor wells. I have reviewed the records of drilling and completion operations for the two EPA monitor wells (Field Activity Log A, June 2010; Field Activity Log B, June-July 2010; Field Activity Log C, July 2010; Field Activity Log D, July-August 2010 and Field Activity Log E, September-October 2010). The Locker MW02, had mud weights up to 10.6 lbs/gal (0.551 psi/ft) while drilling the lower portion of the well. The Randall MW01, had mud weights up to 10.1 lbs/gal (0.525 psi/ft) while drilling the lower portion of the well. These are overbalanced drilling conditions based on static water levels observed later in the monitor wells. The static water level in the Locker MW02 in April 2011 was 264' below top of casing (706' above mid screen depth). The static water level in the Randall MW01 in April 2011 was 201' below top of casing (574' above mid screen depth). It is likely that significant drilling fluid losses occurred to the aquifers during drilling operations.

Locker MW02 static mud pressure at mid screen depth while drilling =

$$0.551 \text{ psi/ft.} \times 970 \text{ ft.} = 534 \text{ psi}$$

Locker MW02 hydrostatic aquifer pressure at mid screen depth =

$$0.433 \text{ psi/ft.} \times 706 \text{ ft.} = 306 \text{ psi}$$

Locker MW02 overbalance while drilling screened interval =

$$534 \text{ psi} - 306 \text{ psi} = \underline{\underline{229 \text{ psi}}}$$

Randall MW01 static mud pressure at mid screen depth while drilling =

$$0.525 \text{ psi/ft.} \times 775 \text{ ft.} = 407 \text{ psi}$$

Randall MW01 hydrostatic aquifer pressure at mid screen depth =

$$0.433 \text{ psi/ft.} \times 574 \text{ ft.} = 249 \text{ psi}$$

Randall MW01 overbalance while drilling screened interval =

$$407 \text{ psi} - 249 \text{ psi} = \underline{\underline{158 \text{ psi}}}$$

The open hole resistivity logs from several offset wells show a significant invasion profile in most porous intervals. This is a clear indication of drilling fluid loss and invasion during the drilling process. It is almost certain there were significant drilling fluid losses during the overbalanced drilling of the two deep monitor wells. This lost fluid must be documented during the drilling of the monitor wells and then accounted for during monitor well development and purging prior to water sampling in order to collect stabilized and representative aquifer samples.

3. Failure to identify the chemical nature of the portland cement used to cement the casing of the two deep EPA monitor wells and to fill the open hole section below the Randall MW01 screened interval. The Draft Report provides considerable details of the properties of the drilling mud additives used while drilling the two deep monitor wells (Draft Report Pg. 7-8), but the Draft Report neglects to provide the properties of the portland cement used in completing the wells.

The pH of portland cement in water ranges from 12 to 13 according to the Material Safety and Data Sheets (MSDS) for portland cement **Figure 1**. Cement and cement losses during the cementing of the open hole below the screened interval in the Randall MW01 and during the casing cementing procedures in both deep monitor wells could easily be the source of the base which produced the observed elevated pH levels in the monitor wells. The Draft Report makes a weak attempt to address this issue (Draft Report Pg. 20), but provides no supporting data (e.g., how much portlandite was actually measured??? When and where was portlandite measured???). Portlandite is not listed as a component or trace ingredient of portland cement according to the portland cement MSDS **Figure 1**.

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**Section 2 - COMPONENTS****Hazardous Ingredients**

Portland cement clinker (CAS# 65997-15-1) - approximately - 93.5-96.0 % by weight  
 ACGIH TLV-TWA (2000) = 10 mg total dust/m<sup>3</sup>  
 OSHA PEL (8-hour TWA) = 50 million particles /ft<sup>3</sup>

Gypsum (CAS# 7778-18-9) - approximately - 4.0-6.5 % by weight  
 ACGIH TLV-TWA (2000) = 10 mg total dust/m<sup>3</sup>  
 OSHA PEL (8-hour TWA) = 15 mg total dust/m<sup>3</sup>  
 OSHA PEL (8-hour TWA) = 5 mg respirable dust/m<sup>3</sup>

**Portlandite ???**

Respirable quartz (CAS# 14808-60-7) - greater than 0.1% by weight  
 ACGIH TLV-TWA (2000) = 0.05 mg respirable quartz dust/m<sup>3</sup>  
 OSHA PEL (8-hour TWA) = (10 mg respirable dust/m<sup>3</sup>)/(percent silica + 2)

**Trace Ingredients**

Trace amounts of naturally occurring chemicals might be detected during chemical analysis. Trace constituents may include up to 0.75% insoluble residue, some of which may be free crystalline silica, calcium oxide (Also known as lime or quick lime), magnesium oxide, potassium sulfate, sodium sulfate, chromium compounds, and nickel compounds.

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**Section 9 - PHYSICAL AND CHEMICAL PROPERTIES**

Appearance.....	Gray Powder	Odor.....	No distinct odor
Physical state.....	Solid (powder)	pH (in water).....	12 to 13
Solubility in water.....	Slightly soluble (0.1 to 1.0%)	Vapor pressure.....	Not applicable
Vapor density.....	Not applicable	Boiling point.....	Not applicable (i.e., > 1000 C)
Melting point.....	Not applicable	Specific gravity (H2O = 1.0).....	3.15
Evaporation rate.....	Not applicable		

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**Figure1.)** Components, physical and chemical properties of portland cement from a portland cement Material Safety and Data Sheet (MSDS).

Also, pH values decreased between sampling phase III and sampling phase IV in both monitor wells (11.9 to 11.2 in the Randall MW01 and 12.0 to 11.8 in the Locker MW02), indicating the wellbores have not produced enough water to reach equilibrium with the aquifers and additional purging needs to be performed before a stabilized representative sample of aquifer water can be obtained.

- Very limited ground water sampling in the two deep monitor wells. The EPA has based its conclusion "that inorganic and organic constituents associated with hydraulic fracturing have contaminated ground water at and below the depth used for domestic water supply". (Draft Report Pg. 39) on only two sampling events of the deep monitor wells. In my opinion this limited data is entirely insufficient and statistically invalid to generate any final conclusions, particularly when taking into account the variations observed between sampling phase III and sampling phase IV. I strongly recommend that the EPA obtain a statistically meaningful data set by conducting significant additional purging and sampling of the two deep monitor wells to obtain additional data before reaching and releasing any conclusions to the public.
- Insufficient water purge volumes prior to water sampling. The amount of water purged from the monitor wells prior to commencing sampling does not meet suggested EPA minimum requirements. The

**removal of at least three well volumes** is suggested prior to commencing with sampling: EPA (1986), Wilde et al. (1998) and Yeskis and Zavala (2002).

Assuming: J-55 grade 4" monitor well casing; ID = 3.428" = volume of 0.064 ft<sup>3</sup>/linear ft. The static water level in the Locker MW02 in April 2011 was 264' below top of casing (706' above mid screen depth).

Locker MW02 well volume = 0.064 ft<sup>3</sup>/ft x 706 ft = 45.25 ft<sup>3</sup> = 1,283 L

Locker MW02 suggest minimum EPA purge volume = 3 x 1,283 L = **3,850 L**

This compares to the "approximately 1,249 L" (less than one well volume) reported purged prior to sampling phase IV (Draft Report Pg. 12).

Assuming: J-55 grade 4" monitor well casing; ID = 3.428" = volume of 0.064 ft<sup>3</sup>/linear ft. The static water level in the Randall MW01 in April 2011 was 201' below top of casing (574' above mid screen depth).

Randall MW01 well volume = 0.064 ft<sup>3</sup>/ft x 574 ft = 36.79 ft<sup>3</sup> = 1,043 L

Randall MW01 suggest minimum EPA purge volume = 3 x 1,043 L = **3,129 L**

This compares to the "approximately 1,117 L" (just over one well volume) reported purged prior to sampling phase IV (Draft Report Pg. 12).

Additionally, accurate purge volumes are not presented in the report or supporting documents, only approximate purge volumes are summarized: "Purge volumes prior to sampling ranged from about 200 to 450 L (Phase III) and 1100 to 1250 L (Phase IV)" (Draft Report Pg. 11), "The total volume of water purged at the start of sampling was approximately 1117 L" (Draft Report Pg. 12) and "Sampling was initiated after approximately 1249 L of water were removed" (Draft Report Pg. 12).

The chemistry of the stagnant water stored in the well casing is unrepresentative of that in the aquifer, and thus that water should not be collected for analysis Barcelona et al. 1985. With an improperly purged well, the stagnant water above the pump will mix with water flowing into the well from the aquifer resulting in a non-representative aquifer water sample.

6. Invalid non-stabilized, non-representative ground water samples were used to reach the final Draft Report conclusions. The final draft conclusion "that inorganic and organic constituents associated with hydraulic fracturing have contaminated ground water at and below the depth used for domestic water supply" (Draft Report Pg. 39) appears to be based in large part on the data presented in Table 3 of the report (Draft Report Pg. 24). In analyzing the results presented in Table 3, it is clear that the aquifer has not stabilized between the time of Phase III sampling and the time of Phase IV sampling.

Of the nine compounds detected in the Randall MW01 monitor well, six of the compounds exhibited changes in concentration in excess of 20% from sampling phase III to Sampling phase IV **Table 1**. Of the 15 compounds detected in the Locker MW02 monitor well, eight of the compounds exhibited changes in concentration in excess of 20% from sampling phase III to sampling phase IV **Table 2**. As a result, the data presented in Draft Report Table 3 is in all probability not representative of actual aquifer water.

<b>Randall MW-1 (MW01)</b>				
<b>Compound</b>	<b>MW01, Phase III 10/06/2010</b>	<b>MW01, Phase IV 04/20/2011</b>	<b>Change</b>	<b>% Change</b>
pH	11.90	11.20	-0.70	-5.88%
K, mg/L	54.90	24.70	-30.20	-55.01%
Cl, mg/L	23.30	23.10	-0.20	-0.86%
CH <sub>4</sub> , mg/L	16.00	17.90	1.90	11.88%
Benzene				
Toluene	0.75	0.56	-0.19	-25.33%
Ethylbenzene				
Xylenes				
1,2,4 Trimethylbenzene				
1,3,5 Trimethylbenzene				
Diesel Range Organics	634.00	924.00	290.00	45.74%
Gasoline Range Organics	389.00	592.00	203.00	52.19%
Phenol	11.10	20.90	9.80	88.29%
Naphthalene				
Benzoic Acid	212.00	457.00	245.00	115.57%

Values shown are in micro-grams/liter unless otherwise noted.

**Table 1.)** Data for the Randall MW-1 (MW01) obtained from Draft Report Table 3 (Draft Report Pg. 24). Of the nine compounds detected in the Randall MW-1 (MW01) monitor well, six of the compounds exhibited changes in concentration in excess of 20% from sampling phase III to sampling phase IV.

Since there was a relatively short period of time and relatively little water was produced from the monitor wells between the time when the monitor wells were developed and the timing of the sampling it is likely that the samples are non-stabilized and non-representative of the actual aquifer waters. It is clear more water needs to be produced or purged from both monitor wells before stabilized representative water samples can be collected from the aquifers.

The high turbidity measurements observed while sampling the Locker MW02 (24.0 – 28.0 NTU's), the variable specific conductance readings (Draft Report Figure 9., Pg. 13) and the constantly declining oxidation-reduction potential readings during sampling (Draft Report Figure 9., Pg. 13) are additional indications that the wellbore has not produced enough water to reach equilibrium with the aquifer, and therefore is not producing stabilized and representative aquifer water.

<b>Locker MW-1 (MW02)</b>				
<b>Compound</b>	<b>MW02, Phase III 10/06/2010</b>	<b>MW02, Phase IV 04/20/2011</b>	<b>Change</b>	<b>% Change</b>
pH	12.00	11.80	-0.20	-1.67%
K, mg/L	39.50	43.60	4.10	10.38%
Cl, mg/L	466.00	457.00	-9.00	-1.93%
CH <sub>4</sub> , mg/L	19.00	18.80	-0.20	-1.05%
Benzene	246.00	139.00	-107.00	-43.50%
Toluene	617.00	336.00	-281.00	-45.54%
Ethylbenzene	67.00	21.50	-45.50	-67.91%
Xylenes	750.00	362.00	-388.00	-51.73%
1,2,4 Trimethylbenzene	69.20	18.50	-50.70	-73.27%
1,3,5 Trimethylbenzene	35.50	0.00	-35.50	-100.00%
Diesel Range Organics	1,440.00	4,050.00	2,610.00	181.25%
Gasoline Range Organics	3,710.00	2,800.00	-910.00	-24.53%
Phenol	56.10	64.90	8.80	15.69%
Naphthalene	6.06	6.10	0.04	0.66%
Benzoic Acid	244.00	209.00	-35.00	-14.34%

Values shown are in micro-grams/liter unless otherwise noted.

**Table 2.)** Data for the Locker MW02 obtained from Draft Report Table 3 (Draft Report Pg. 24). Of the 15 compounds detected in the Locker MW02 monitor well, eight of the compounds exhibited changes in concentration in excess of 20% from sampling phase III to sampling phase IV.

7. Laboratory errors, contamination questions and non-repeatable laboratory results. There are several examples in the Draft Report where contamination is detected in blank control samples which are supposed to consist of pure distilled water. This is evidence of potential laboratory errors and/or contamination and raises additional questions about the validity and accuracy of all of the EPA data used in the study. The Draft Report also raises serious questions about the reliability and repeatability of the analytical methods used by the EPA to obtain the data which the study results are based upon.
  - Some blank samples showed detections of acetone, m,p-xylene, toluene, benzoic acid and tetraethylene glycol (Draft Report Pg. 14). In at least three aquifer water samples reported in Draft Report Table 3 (Draft Report Pg. 24) levels of toluene, xylenes and tetraethylene glycol were detected at similar levels to the levels detected in blank control samples. These samples are identified by: "d Chemical detected in blank samples at a similar level". Where did this contamination come from?

- Elevated concentrations of diesel range organics were detected in one of six blank samples (Draft Report Pg. 14). Where did this contamination come from?
  - In water samples collected from the two deep EPA monitor wells, one in eight samples had a detection of 2-Butoxyethanol (2-BE). In the well where 2-BE was detected, two of the three EPA labs conducting testing did not recognize 2-BE in duplicate samples. This raises suspicion of the EPA's ability to detect minute quantities of 2-BE, and the question: Was 2-BE actually present in any of the samples or is this simply a result of contamination? How can the EPA conclude that 2-BE is present based on this conflicting data?
  - The EPA admits the need for "continued and future improvements of analytical methods to detect and quantitate low levels of organic chemicals that may be associated with hydraulic fracturing fluids" (Draft Report Pg. 27). This is in part due to unexplained inconsistencies in detecting glycols when comparing the results of gas chromatology combined with flame ionization to the results of liquid chromatology combined with mass spectroscopy. Evidently the gas chromatology combined with flame ionization (EPA Standard Method 8015) is prone to false positive results (Draft Report Pg. 27). Which of these methods was used to analyze for glycols the water samples obtained from the two deep EPA monitor wells during sampling phases III and IV? Was EPA Standard Method 8015 which is evidently prone to false positive results used to detect glycol concentrations in the monitor well water samples?
  - The EPA apparently also used its own proprietary methods to analyze samples: "Detection of synthetic organic compounds was made in part through the use of non-commercially available modified EPA analytical methods (Draft Report Pg. 35) ". Have these EPA methods and results ever been verified and confirmed for accuracy by any independent outside sources?
8. No attempt was made to document what was specifically used to hydraulically fracture stimulate specific gas production wells in the vicinity of the monitor wells and what specific stratigraphic intervals were hydraulically fracture stimulated. In several sections of the draft report the EPA references chemical components used to hydraulically fracture stimulate wells:

"Potassium hydroxide was used in a crosslinker and in a solvent at this site" (Draft Report Pg. xii), "The formulation of fracture fluid provided for carbon dioxide foam hydraulic fracturing jobs typically consists of 6% potassium chloride. Potassium metaborate was used in crosslinkers. Ammonium chloride was used as a crosslinker" (Draft Report Pg. xii), (Isopropanol was used in a biocide, in a surfactant, in breakers and in foaming agents. Diethylene glycol was used in a foaming agent and in a solvent. Triethylene glycol was used as a solvent. Tert-butyl alcohol is a known breakdown product of methyl tert-butyl ether and tert-butyl hydroperoxide (a gel breaker used in hydraulic fracturing) (Draft Report Pg. xii), "Aromatic solvent (typically BTEX mixture) was used as a breaker. Diesel oil (mixture of saturated and aromatic hydrocarbons including naphthalenes and alkylbenzenes) was used in a guar polymer slurry/liquid gel concentrate and in a solvent. Petroleum raffinates (mixture of paraffinic, cycloparaffinic, olefinic and aromatic hydrocarbons) were used in a breaker. Heavy aromatic petroleum naphtha (mixture of paraffinitic, cycloparaffinitic and aromatic hydrocarbons) was used in surfactants and in a solvent. Toluene and xylene were used in flow enhancers and a breaker" (Draft Report Pg. xii), "Well completion reports obtained online from WOGCC and Material Safety and Data Sheets (MSDS's) obtained from the operator were reviewed to examine inorganic and organic compounds in additives used for hydraulic fracturing and similarity with detected elements and compounds in ground

water (Draft Report Pg. 23), Table 4 (Draft Report Pg. 26), "Material Safety Data Sheets indicate that potassium hydroxide was used in a crosslinker (<5%) and in a solvent" (Draft Report Pg. 34), "Information from well completion reports and Material Safety Data Sheets indicate that the formulation of fracture fluid provided for foam jobs typically consisted of 6% potassium chloride. Potassium metaborate was used in crosslinkers (5-10%, 30-60%). Potassium hydroxide was used in a crosslinker (<5%) and in a solvent. Ammonium chloride was used in crosslinker (1-27%)" (Draft Report Pg. 34), "Tert-butyl alcohol is a known breakdown product of methyl tert-butyl ether (a fuel additive) and tert-butyl hydroperoxide (a gel breaker used in hydraulic fracturing)" (Draft Report Pg. 35), "Material Safety Data Sheets indicate that isopropanol was used in a biocide (20-40%), in a surfactant (30-60%), in breakers, (<1%, 10-30%), and foaming agents (<3%, 1-5%, 10-30%). Diethylene glycol was used in a foaming agent (5-10%) and in a solvent (0.1-5%). Triethylene glycol was used in a solvent (95-100%)" (Draft Report Pg. 35), "Material Safety Data Sheets indicate that aromatic solvent (typically BTEX mixture) was used in a breaker (<75%). Diesel oil (mixture of saturated and aromatic hydrocarbons including naphthalenes and alkylbenzenes) was used in a guar polymer slurry/liquid gel concentrate (30-60%) and in a solvent (60-100%). Petroleum raffinates (a mixture of paraffinic, cycloparaffinic, olefinic and aromatic hydrocarbons) were used in a breaker (<30-60%). Heavy aromatic petroleum naphtha (mixture of paraffinic, cycloparaffinic and aromatic hydrocarbons) was used in surfactants (5-10%, 10-30%, 30-60%) and in a solvent (10-50%). Toluene was used as a flow enhancer (3-7%). Xylenes were used in a flow enhancer (40-70%) and a breaker (confidential percentage) Draft Report Pg. 35-36).

The Draft Report is unclear if these chemical components were actually documented as specifically used in the Pavillion area or are just generally known to be used by industry as a whole in the hydraulic fracturing process.

If these components were documented as specifically used in the Pavillion area, then why were the known well locations and stratigraphic intervals with specific chemical components known to the EPA not specifically documented and mapped as part of the study? It is critically important to understand what components were used to hydraulically fracture stimulate specific wells and specific stratigraphic intervals since a highly concentrated contaminant plume will exist in the zone of injection with dispersed and diluted lower concentration areas vertically and laterally distant from the injection point EPA (2004).

For Example: The Encana Pavillion Fee 41-10B is one of the closest offsetting gas production wells (629' to the east) to the EPA Randall MW01 monitor well. The shallowest completion stage in the Encana Pavillion Fee 41-10B occurred at a depth of 1,792-1,799' (approximate 1,007' below the depth of the EPA Randall MW01 screened interval). This completion stage consisted of a hydraulic fracture stimulation composed of 48 bbls slickwater and 11,625 lbs sand (**Sean Kelly-Attachment No. 3**). A slickwater completion does not contain gel or CO2 foam and thus would not require the crosslinkers, breakers or foaming agents EPA (2004) which are the most frequently cited primary sources of deep contamination in the Draft Report. Potential contamination from crosslinkers, breakers or foaming agents would have to come from gas production wells more distant and more diluted than the Encana Pavillion Fee 41-10B.

A Second Example: The Encana Tribal Pavillion 12-12 is one of the closest offsetting gas production wells (399' to the west) to the EPA Locker MW02 monitor well. The shallowest completion stage in the Encana Tribal Pavillion 12-12 occurred at a depth of 1,964-2,025' OA (approximate 984' below the depth of the EPA Locker MW02 screened interval). This completion stage consisted of a hydraulic fracture stimulation composed of 96 bbls slickwater and 30,664 lbs sand (**Sean Kelly-Attachment No. 3**). A

slickwater completion does not contain gel or CO<sub>2</sub> foam and thus would not require the crosslinkers, breakers or foaming agents EPA (2004) which are the most frequently cited primary sources of deep contamination in the Draft Report. Potential contamination from crosslinkers, breakers or foaming agents would have to come from gas production wells more distant and more diluted than the Encana Tribal Pavillion 12-12.

In addition, the meanings of the percentages given in Table 4 (Draft Report Pg. 26), and throughout the Draft Report are never explained and are unclear. Are they the percentage of overall stimulations which used the compounds? Are they the percentage of compounds used in a given component used in a well stimulation? Are they the volume percentage of a compound in a given well stimulation? The EPA needs to clarify this data.

#### **Summary of Draft Report Major Deficiencies:**

1. No easily discernible location maps. All of the maps included in the Draft Report are extremely difficult to read, almost illegible. It took considerable effort just to identify the section and township location of the study.
2. Extremely poor records of operations and completions – illegible. Operational reports and records of drilling and developing the two deep EPA monitor wells are very poorly organized and often illegible. Reports should be in chronological order on a well by well basis rather than all activities for both wells grouped into a single daily report. The industry standard is for reports to be typed rather than hand written. Much of the handwriting in the reports is illegible.

**Nowhere in the Draft Report, operation records, sample logs or supporting data is information as basic as the ground and/or reference elevation for the drilling of the two deep EPA monitor wells provided. The reference elevation is required to calculate structural elevations and the elevation of the potentiometric surface in the two deep EPA monitor wells.**

3. Release of open hole logs run in the two deep EPA monitor wells. At the cessation of drilling, open hole geophysical logging (caliper, density, resistivity, spontaneous potential and natural gamma) was conducted by Colog Inc., prior to placement of well construction materials (Draft Report Pg. 8-11). The only open hole logs from the EPA monitor wells provided as part of the Draft Report or supporting documentation is an extremely compressed versions of the 16" normal resistivity logs (Figure 7, Draft Report Pg. 11). This is entirely insufficient open hole log data for anyone attempting to evaluate the formations encountered in the two deep EPA monitor wells.

Also, the EPA should have included a compensated neutron log as part of the open hole logging suite in the two deep monitor wells. Based on observations of natural gas productive reservoirs encountered in gas productive wells, the presence of producible natural gas in upper Wind River Formation reservoirs in the Pavillion Field area appears to be directly indicated by neutron – density log cross over or "gas effect" (Sean Kelly Attachment-No.3). The compensated neutron log is a fairly simple and inexpensive log to run, and is critical to the evaluation of natural gas bearing intervals. The failure to run a compensated neutron log when evaluating the presence of natural gas would be an egregious and unexplainable oversight on the part of the EPA.

4. Release of cement bond/variable density logs on the two deep EPA monitor wells demonstrating mechanical integrity and producing aquifer isolation from shallow zones. Did the EPA run cement bond/variable density logs in the two deep monitor wells? If cement bond/variable density logs were run, the data needs to be provided. If cement bond/variable density logs were not run, what proof is there of wellbore mechanical integrity and producing aquifer isolation from shallow zones which were shown to contain contamination from surface pits?
5. The EPA interpretations rely almost entirely upon chemistry detections and analysis. The geological interpretations presented in the Draft Report are woefully inadequate and hydrological interpretations are nonexistent.

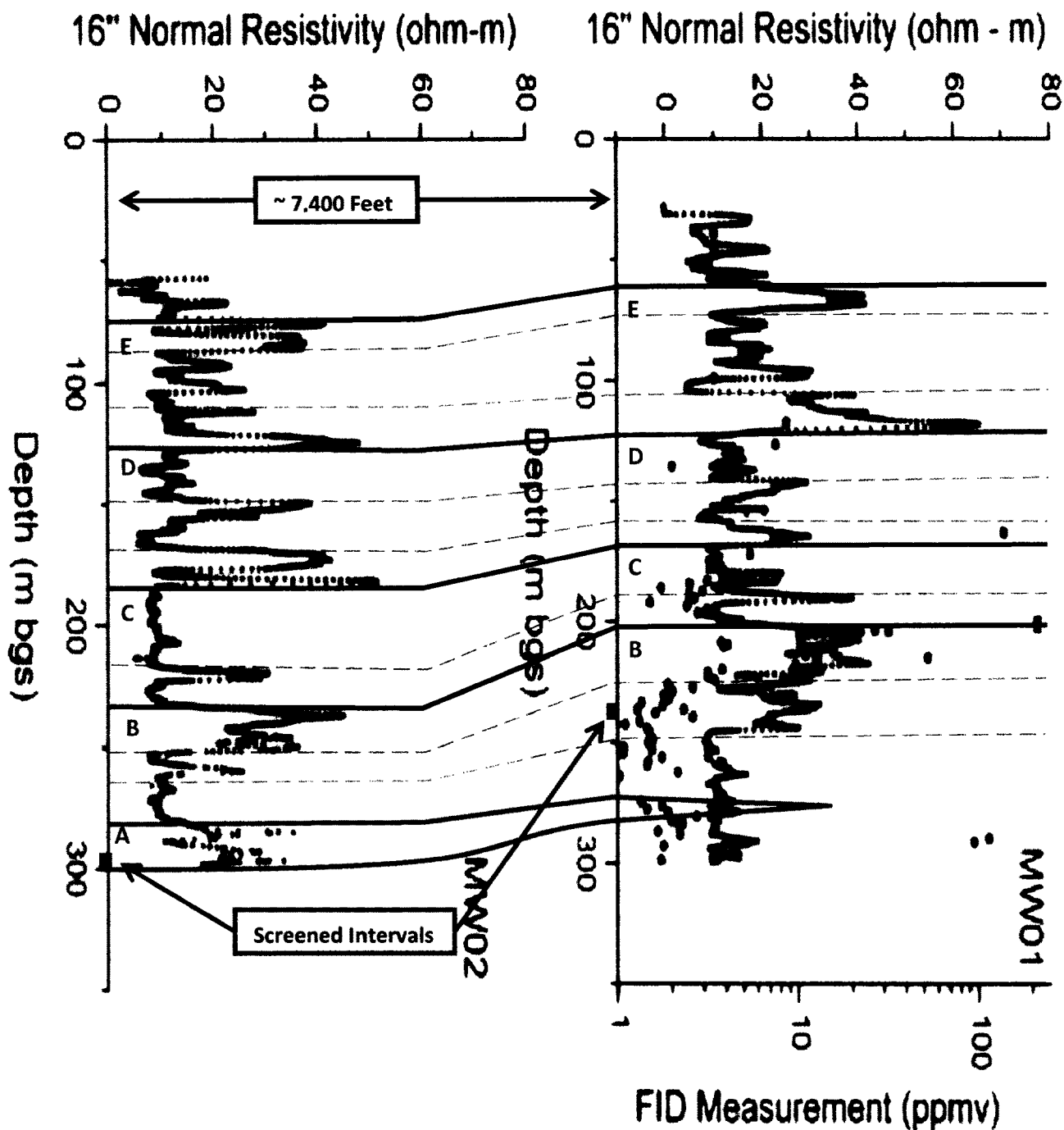
The Draft Report references a few previously published papers on general Wind River Formation and Wind River Basin geology on Pg. 2, and provides a very general Wind River Basin stratigraphic column on Pg.3. On Draft Report Pg. 15, Wind River Formation geology is summarized as: "Lithology in the area of investigation is highly variable and difficult to correlate from borehole to borehole, even for boreholes in close proximity to one another consistent with other observations in the Wind River Formation (Osiensky 1984). Sandstone and shale layers appear thin and of limited lateral extent, again consistent with previous observations of lithology in the Wind River Formation (Single 1969, Flores and Keighin 1993)."

A review of the Flores and Keighin (1993) paper finds that this study concentrates on the Fort Union Formation stratigraphy and does not mention specific information on Wind River Formation stratigraphy, so it should not be used by the EPA as a reference on Wind River Formation stratigraphy.

On Draft Report Pg. 15, it is stated "Borehole geophysical logs available on line from WOGCC were utilized to map lithology in the area of investigation". Nowhere in the Draft Report or supporting documents are any of these maps presented.

A "lithologic cross-section" is presented on Figure 20, Draft Report Pg. 31. A rudimentary attempt is made to correlate "sandstones" and "shales" (gray vs. white) without taking into account structural variations along the line of section. The Draft Report does not explain how "sandstones" and "shales" are differentiated. On Pg. 32 the geologic summary of Figure 20 is provided: "As illustrated in Figure 20, there is little lateral and vertical continuity to hydraulically fractured tight sandstones and no lithologic barrier (laterally continuous shale units) to upward vertical migration of aqueous constituents of hydraulic fracturing in the event of excursion from fractures".

**The EPA has not performed the basic geological analyses and interpretations required to make and support the statement "there is little lateral and vertical continuity to hydraulically fractured tight sandstones and no lithologic barrier (laterally continuous shale units) to upward vertical migration of aqueous constituents of hydraulic fracturing in the event of excursion from fractures".** The EPA should begin by closely examining the log data from the two deep monitor wells shown in Draft Report Figure 7, (Draft Report Pg. 11). Contrary to what is stated in Draft Report Pg. 32, it is quite obvious there is actually good to excellent lateral stratigraphic continuity over the approximately 7,400 ft. separating the two deep EPA monitor wells **Figure 2**. Individual sandstone prone intervals (higher resistivity) and shale prone intervals (lower resistivity) show good to excellent continuity between the two deep EPA monitor wells (see markers B, C, D and E, and the dashed lines on **Figure 2**.).

**Figure 7.** Resistivity as a function of depth in MW01

**Figure 2.)** Modified from Draft Report Figure 7, (Draft Report Pg. 11). Intervals in the upper Wind River Formation exhibit a good to excellent lateral stratigraphic continuity between the two deep EPA monitor wells.

It may be true that sandstone intervals in the lower Wind River Formation and Fort Union Formation are for the most part thin and have limited lateral extent as stated in Single (1969) and Bjorklund (1978), but this is not true of the upper Wind River Formation. There is good lateral continuity in the upper Wind River Formation from depths of approximately 1,500' up to depths of approximately 900'. This is demonstrated by the log responses and correlations of the informal Wind River stratigraphic tops: TWR-A0, TWR-A1, TWR-A2 and TWR-A on **Sean Kelly-Attachment No.2** and **Sean Kelly-Attachment No.3**. There is excellent lateral continuity in the upper Wind River Formation from depths of approximately 900' to the surface. This is demonstrated by the log responses and correlations of the informal Wind River stratigraphic tops: TWR-B1, TWR-B2, TWR-B, TWR-C1, TWR-C, TWR-D1, TWR-D2, TWR-D, TWR-E1, TWR-E2, TWR-E and TWR-F on **Sean Kelly-Attachment No.2** and **Sean Kelly-Attachment No.3**.

There are two laterally continuous shale dominated intervals that almost certainly act as barriers to any upward migration of the aqueous constituents of the hydraulic fracture stimulation process and also as an intermediate seal to natural hydrocarbon migration. Shale intervals in this area are easily recognized by open hole log responses utilizing a shale baseline resistivity of 7-10 ohm-m combined with gamma ray readings in excess of 75 API units.

- The lower laterally continuous intermediate seal is located between the informal Wind River stratigraphic tops TWR-B and TWR-C. This lower interval ranges in gross thickness from 85 to 160' thick. Sandstones containing natural gas (as proven from production tests or calculated from open hole logs) are very common below this lower laterally continuous intermediate seal (**Sean Kelly-Attachment No.3**). Both deep EPA monitor wells are screened below this lower laterally continuous intermediate seal and so the fact that methane, benzene, BTEX compounds and other hydrocarbons were detected at high concentrations should have been expected. Furthermore, any aquifers located below the lower laterally continuous intermediate seal in the area of lower Wind River Formation structural closure should be expected to contain significant concentrations of naturally occurring hydrocarbons and thus be exempt from USDW classification. United States Code of Federal Regulations, Title 40, Section 146.4.
- The upper laterally continuous intermediate seal is located between the informal Wind River stratigraphic tops TWR-E and TWR-F. This upper interval ranges in gross thickness from 50 to 70' thick (**Sean Kelly-Attachment No.3**). Natural gas bearing intervals are less common between the top of the lower laterally continuous intermediate seal and the base of the upper laterally continuous intermediate seal but are still present as indicated by the sandstone located from 565-573' in the Encana Pavillion Fee 11-11B, and the sandstone located from 541-551' in the Tom Brown Pavillion Fee 41-10 and from the blowout that occurred at 522' while attempting to drill a new domestic water well at the PGDW45 location (**Sean Kelly-Attachment No.3**).

There are only a few brief references to the local hydrology in the entire Draft Report, and the Draft Report conclusions presented on the local hydrology are oversimplified and in error. On Pg. xiii the Draft Report States: "However, there are flowing conditions in a number of deep stock wells suggesting that upward gradients exist in the area of investigation". On Pg. 36 the Draft Report States: "Hydraulic gradients are currently undefined in the area of investigation. However, there are flowing stock wells (e.g., PGDW44 – one of the deepest domestic wells in the area of investigation at 229 m below ground surface) suggesting that upward gradients exist in the area of investigation."

To actually determine if an “upward gradient” exists in the area, a much more thorough and rigorous hydrodynamic investigation must be performed by the EPA. To analyze fluid flow directions, the potentiometric gradient in an area must first be determined, this is usually accomplished by generating a potentiometric surface elevation map. The presence of “flowing conditions” indicates the aquifer’s potentiometric surface is above ground level at those locations. Both deep EPA monitor wells had potentiometric surfaces well below ground level at their locations (April 2011 water levels). Assuming the deep stock wells and the deep EPA monitor wells are in hydrodynamic communication, then flow would actually be away from the stock wells with the higher potentiometric elevations and towards the deep EPA monitor wells with the lower potentiometric elevations. In this case, the potentiometric surface and the gradient would actually be downward, not upward as incorrectly stated in the Draft Report.

It is absolutely amazing that the EPA would attempt to conduct a groundwater contamination investigation without first evaluating the local geology and hydrology. The local geology and hydrology will control the migration of naturally occurring hydrocarbons and ground water flow. Potential contamination pathways will in large part also be controlled by the local geology and hydrology. To properly conduct a groundwater investigation of this scale the EPA should expect to analyze an area of interest of approximately nine sections in size. At a minimum the following procedures must be performed:

- a. Data compilation: Begin with a decent base map which identifies all well locations on a standard Jeffersonian survey grid. Compile all available well data for the wells located in the area of interest which should include the well drilling and completion reports, open hole logs, mud logs, cement bond/variable density logs and production records.
- b. Establish the local stratigraphic framework: Correlate important stratigraphic surfaces and markers throughout the area of interest by constructing a grid of correlation cross sections utilizing open hole and if necessary cased hole logs. An example of a correlation cross section along with suggested important stratigraphic surfaces and markers for the upper portion of the Wind River Formation are shown in **Sean Kelly-Attachment No.2**. Complete the local stratigraphic framework by correlating the important stratigraphic surfaces and markers to wells not included on the grid of correlation cross sections.
- c. Petrophysical analysis: Open hole log data must first be normalized across the area of interest. This would include normalizing the cased hole gamma ray log responses for gamma ray logs to match open hole gamma ray log response. Once the log data is normalized, volume of shale calculations, porosity calculations and water saturation calculations can be performed. It is then possible to determine the petrophysical responses of hydrocarbon bearing intervals, intervals with partial hydrocarbon saturations and intervals which contain water by comparing the petrophysical calculations to actual well test results. Zones which have the potential to act as barriers to hydrocarbon and fluid flow due to low porosity and permeability or high shale volume can also be identified.
- d. Mapping: At a minimum structure maps should be created for important stratigraphic surfaces. This is also helpful to verify log correlation accuracy. Gross thickness and net reservoir isopach maps should be generated for the prominent potential reservoir intervals

(water and/or hydrocarbon bearing) and gross thickness isopach maps should be generated for all prominent potential barrier intervals. For groundwater contamination studies, potentiometric surface maps must be constructed for all prominent aquifers. This will aid in determining which aquifers are in hydrodynamic communication and determining preferred ground water flow directions.

- e. Construction of detailed geologic cross sections: All available well test data, the stratigraphic framework, the petrophysical calculations, the identified potential reservoirs (water and/or hydrocarbon bearing), the identified barriers to hydrocarbon and fluid flow and any other and other pertinent information can be integrated in detailed geological cross sections. An example of a detailed geologic cross section is shown in **Sean Kelly-Attachment No.3**.
- f. Analysis of the petroleum and hydrological systems: By integrating structure maps, isopach maps, cross sections, petrophysical data and well test data it is possible to determine the areas where naturally occurring hydrocarbons are most likely to accumulate and in what stratigraphic intervals they are most likely to accumulate. By integrating well specific and zone specific well stimulation procedures and data with maps and cross sections, the EPA would have been able to document what chemical compounds were used to stimulate specific stratigraphic intervals across the area of interest. By mapping the potentiometric surfaces the EPA could make an estimate of ground water flow directions and an estimate of possible contamination movement, where potential contamination plumes may exist, and what compounds could be expected in the potential contamination plumes.
- g. Finally, it is critical to understand the present day natural stresses for a study such as this which attempts to determine the movement of fluids through hydraulically induced fracture systems. Hydraulically induced fracture will preferentially propagate in a direction parallel to the present day maximum stress direction. This is a critical piece of information used to determine the direction of potential fluid migration and to identify areas that may be affected and to eliminate other areas that will probably not be affected by the hydraulic fracture stimulation process. Unfortunately, this was totally neglected in this study.

This is the minimum background geologic and hydrologic work that should have been completed by the EPA prior to planning and siting the two deep monitor wells. This is also the minimum background investigation that would be expected to be completed in private industry prior to initiating a hydrocarbon development or exploration drilling program.

This recommended procedure is in contrast to the methods used in the Draft Report where the EPA has grouped all known chemical compounds potentially "associated" with the hydraulic fracture stimulation process in the area into a single data set and attempted to identify the presence of any of these compounds or any possible natural breakdown products of any of these compounds in the EPA monitor wells without considering the location (both areally and stratigraphically) where the chemical compounds were actually used. It is critically important to understand what compounds were used to hydraulically fracture stimulate specific wells and specific stratigraphic intervals since a highly concentrated contaminant plume will exist in the zone of injection with dispersed and diffused lower concentration areas vertically and laterally distant from the injection point EPA (2004).

6. The EPA appears to have a lack of understanding of the natural variations in ground water both locally and regionally in the Pavillion area. The EPA has failed to recognize that the quality of the ground water in the area northeast of the town of Pavillion has historically been "marginal at best". Extensive research has been conducted and several water resource studies have published data documenting the poor ground water quality in the Pavillion area McGreevy et al. (1969), Plafcan (1995), Daddow (1996), Mason et al. (2005) and Gore & Associates (2011). A study commissioned by the Wyoming Water Development Commission concluded there were no surface location or drilling depths at which palatable groundwater can be readily found in this area, and that getting a domestic well with good water was always an "uncertain venture" Gores & Associates (2011). For example, a water sample collected from the PDGW05 well on August 19, 1991 (prior to extensive natural gas activities in the area) had TDS values of 1,430 mg/L (almost three times the EPA secondary maximum contamination level of 500 mg/L) and dissolved sulfate values of 860 mg/L (over three times the EPA secondary maximum contamination level of 250 mg/L) Plafcan (1995) Pg. 66-67.

The water quality in the Wind River Formation in the area of Pavillion Field did not suddenly degrade with the onset of natural gas development in the area. The poor ground water quality is a function of the area's arid climate combined with the geology, long ground water residence time and low ground water recharge rates Mason (2005). The chemical quality and ionic composition of water samples collected from the Wind River Formation are variable even over very short distances because the formation has highly variable lithology, permeability and recharge conditions Daddow (1996). In the Pavillion area, Wind River Aquifer water is typically high in total dissolved solids (TDS levels from 211 to 5,110 mg/L were measured) with sodium and sulfates typically found in concentrations exceeding the EPA secondary drinking water standards Daddow (1996).

7. No chemical analysis (organic and inorganic compounds) of water produced by Pavillion Field gas production wells. Are the same "constituents associated with hydraulic fracturing" that were allegedly detected in the two deep EPA monitor wells also present in the produced water of producing gas wells that offset the monitor wells? Is the pH of water from producing gas wells similar to the pH observed in the two deep EPA monitor wells?

If "constituents associated with hydraulic fracturing have been released into the Wind River drinking water aquifer at depths above the current production zone" (Draft Report Pg. 33), then it would make sense that these same constituents would be present in the water produced in association with the natural gas in gas productive wells. The EPA's own research has shown that components used to hydraulically fracture stimulate an interval will create a highly concentrated plume in the zone of injection with dispersed and diluted lower concentration areas both vertically and laterally distant from the injection point (EPA, 2004). Following this logic, the constituents associated with the hydraulic fracturing process which were allegedly detected in the two deep EPA monitor wells should also be present (and in even higher concentrations) in the water produced by the gas producing wells. Also, if the hydraulic fracture stimulation process is the source of the elevated pH observed in the two deep EPA monitor wells, then similarly elevated pH values would be expected in the water produced by the gas producing wells.

The EPA obtained and analyzed at least five produced water samples from gas producing wells in sampling phase II (Draft Report Pg. A12-A14). Unfortunately, it appears the only analysis performed on these produced water samples was for hydrocarbon content. It is very unfortunate that the EPA failed to

conduct even basic chemical analyses of the water collected from the producing gas wells during sampling phase II.

8. Failure to recognize that thermogenically derived natural gas can migrate vertically over time through natural buoyant and diffusion processes without the presence of 1.) producing wellbores, 2.) "hydraulic fracture stimulation fluid excursion" or 3.) new fractures generated during the hydraulic fracture stimulation process (Draft Report Pg. 32).

Hydrocarbons generated at the depths where source rocks are in the "thermal maturity window" are capable of migrating as a separate immiscible phase through the water saturated pore space of overlying sedimentary strata all the way to the surface. The primary driving force for migration is the vertical buoyancy force created by the density differences between the hydrocarbons and water. Occasionally, hydrocarbons are trapped in the subsurface where they encounter a reservoir rock and a seal rock that are in a three-dimensional configuration capable of impeding the migration along the migration pathway England (1994).

The occurrence and presence of shallow natural gas in the Pavillion area is identified and focused on in two different portions of the Draft Report.

- First, an occurrence where natural gas was encountered at a depth of 522' while attempting to drill a domestic water well: "Use of mud rotary with BOP was necessary given that a blowout occurred during installation of a domestic well at only 159 m (522 ft) bgs in December 2005 in the vicinity of MW01" (Draft Report Pg. 5). "A blowout occurred during drilling at a depth of only 159 m bgs in December 2005 adjacent to PGDW05. Natural gas exited the borehole for three days until the gas field operator was ordered to plug the borehole with a dense mud" (Draft Report Pg. 29). "A blowout occurred during drilling at a depth of only 159 m bgs in December 2005 adjacent to PGDW05" (Draft Report Pg. 38).
- Second, the apparent observation that dissolved methane appears to be more prevalent in domestic wells located in the vicinity of gas production wells: Elevated levels of dissolved methane in domestic wells generally increase in those wells in proximity to gas production wells (Draft Report Pg. xii). Elevated levels of dissolved methane in domestic wells generally increases in those wells in proximity to gas production wells (Figure 18c) (Draft Report Pg. 27). Levels of dissolved methane in domestic wells generally increase in those wells in proximity to gas production wells (Draft Report Pg. 38).

My review and analysis of open hole logs along the same cross section as shown Draft Report Figure 20 (Draft Report Pg. 31) indicates natural gas occurs at very shallow depths above Pavillion Field (**Sean Kelly-Attachment No. 3**). Wind River Formation intervals which have been proven productive of natural gas through perforating and testing in gas productive wells are identified by open hole log responses where the deep resistivity is greater than 20 ohm-m and the neutron-density porosity exhibits crossover or "gas effect" (**Sean Kelly-Attachment No. 3**).

The number and frequency of probable gas intervals decreases in an upward direction. This is consistent with a model of natural gas migration through upward buoyant forces where natural gas migration is driven by density differences and concentration gradients. Natural gas reservoirs are filled as natural gas defuses upward across intermediate seals which act as semi-permeable membranes. Two laterally continuous intermediate seals are identified on logs in the Pavillion Field area (**Sean Kelly-Attachment No. 3**). Through time, the deep thermogenically generated natural gas migrates into shallower strata

and much of the natural gas will even eventually migrate to the surface where it dissipates into the atmosphere.

From my limited observations while reviewing the Draft Report, proven productive gas zones and shallow probable gas intervals are most common in the area of upper Wind River structural closure (**Sean Kelly-Attachment No. 1** and **Sean Kelly –Attachment No. 3**). Probable natural gas occurs as shallow as 565-573' in the Encana Pavillion Fee 11-11B and at 541-551' in the Tom Brown Pavillion Fee 41-10 (**Sean Kelly-Attachment No.3**). Potential shallower natural gas bearing intervals cannot be determined due to the lack of open-hole log data in the surface casing portion of the wells I evaluated.

The fact that natural gas was encountered at a depth of 552' while attempting to drill a domestic water well in the Pavillion Field area should have been expected. Why does the EPA find it unexpected that a well drilled in an area surrounded by shallow natural gas producing wells would eventually encounter a natural gas accumulation at depth? The water well drillers of the failed domestic water well were drilling significantly below the permit depth of 300' when the natural gas bearing interval was encountered at 522' (State of Wyoming, Office of the State Engineer, Permit No. U.W. 170310, dated October 19, 2005). The Encana Pavillion Fee 11-11B is located approximately 1,380' southwest of the location where drilling of the failed domestic water well was attempted. The Encana Pavillion Fee 11-11B has an interval at 565-573' where the open-hole logs have deep resistivity in excess of 100 ohm-m, resistivity invasion profiles indicating good permeability and porosity in excess of 24% with strong "gas effect" on the neutron-density porosity (**Sean Kelly-Attachment No.3**). The Tom Brown Pavillion Fee 41-10 has an interval at 541-551' where the open-hole logs have deep resistivity of 40-65 ohm-m, resistivity invasion profiles indicating good permeability and 26% porosity with strong "gas effect" on the neutron-density porosity (**Sean Kelly-Attachment No.3**). These shallow zones would be capable of producing natural gas in high volumes in a well drilled without the proper pressure control systems. It is probable that the failed domestic water well encountered a natural gas bearing zone similar to the intervals encountered at 565-573' in the Encana Pavillion Fee 11-11B, and at 541-551' in the Tom Brown Pavillion Fee 41-10. Proper due diligence and a review of publically available data on the part of the landowner and water well drilling company would have warned of the potential danger of encountering naturally occurring natural gas at these depths in this area (Too bad Mr. Meeks doesn't own the mineral rights under his land). It is fortunate that no one was injured as a result of this negligence.

The Draft Report attempts to conclude that shallow natural gas was not always present in the area of the failed domestic water well by referencing the mud log from an offset producing natural gas well: "A mud-gas log conducted on 11/16/1980 at Tribal Pavillion 14-2 located only 300 m from the location of the uncontrolled release does not indicate a gas show (distinctive peaks on a gas chromatograph) within 300 m of the surface" (Draft Report Pg. 29). Unfortunately, the EPA conveniently ignored the fact that the surface casing in the Tribal Pavillion was set at 600' and the mud log only begins at 600' when the operator was drilling out of surface casing. Open hole logs were also only run as shallow as the surface casing up to a depth of 600'. It is impossible to determine if the shallow gas bearing zone which caused the uncontrolled release at a depth of 552' in the failed domestic water well is actually present in the Tribal Pavillion 14-2, based on the data that is available for the Tribal Pavillion 14-2.

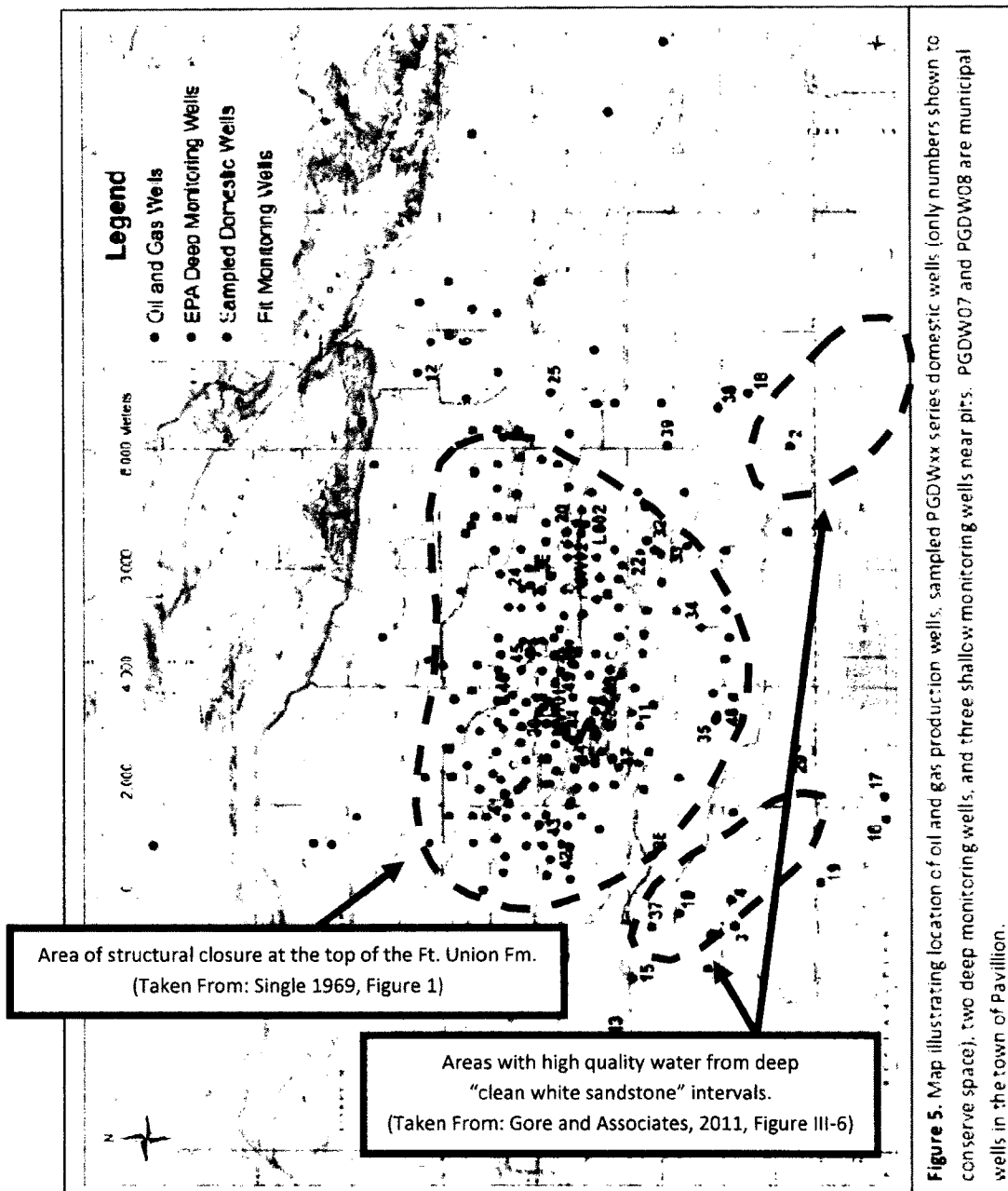
The observation that dissolved methane appears to be more prevalent in domestic water wells located in the vicinity of gas production wells can be easily explained by examining the geology of the area. The trap for the Pavillion Field is formed by a simple anticlinal four-way structural closure. This structural closure is the controlling factor for the natural gas accumulation in Pavillion Field. The vast majority of

gas production wells are located within the area of structural closure **Figure 3** and **Figure 4**. This is the area where natural gas which is thermogenically generated from source rocks buried deeper in the basin has migrated upward through a natural buoyant process and is now trapped in shallower Wind River and Fort Union reservoirs in the area of structural closure. This is how the natural gas accumulation at Pavillion Field naturally formed, and why the gas productive wells are concentrated in the area of structural closure. Natural gas at all depths would be expected to be significantly more prevalent inside of the area of structural closure than in areas outside of the area of structural closure. Any domestic water wells drilled inside the area of structural closure and therefore within the productive limits of Pavillion Field would also be drilled where the concentration of gas productive wells is the greatest (and thus more likely to be located proximal to gas productive wells). Any domestic water wells drilled in the area of structural closure would also be located in the area where natural gas has migrated from deeper sources and has naturally accumulated in shallow strata located within the Pavillion Field anticlinal trap. Even very shallow porous zones located inside of structural closure would be expected to have concentrations of residual or dissolved methane as natural gas migrated through these intervals on the way to the surface (**Sean Kelly-Attachment No.3**).

Two areas with high quality water from deep "clean white sandstone" intervals in close proximity to Pavillion Field are identified by Gore and Associates (2011). These areas of high quality water are located outside of the area of structural closure and therefore outside of the productive limits of Pavillion Field **Figure 3**.

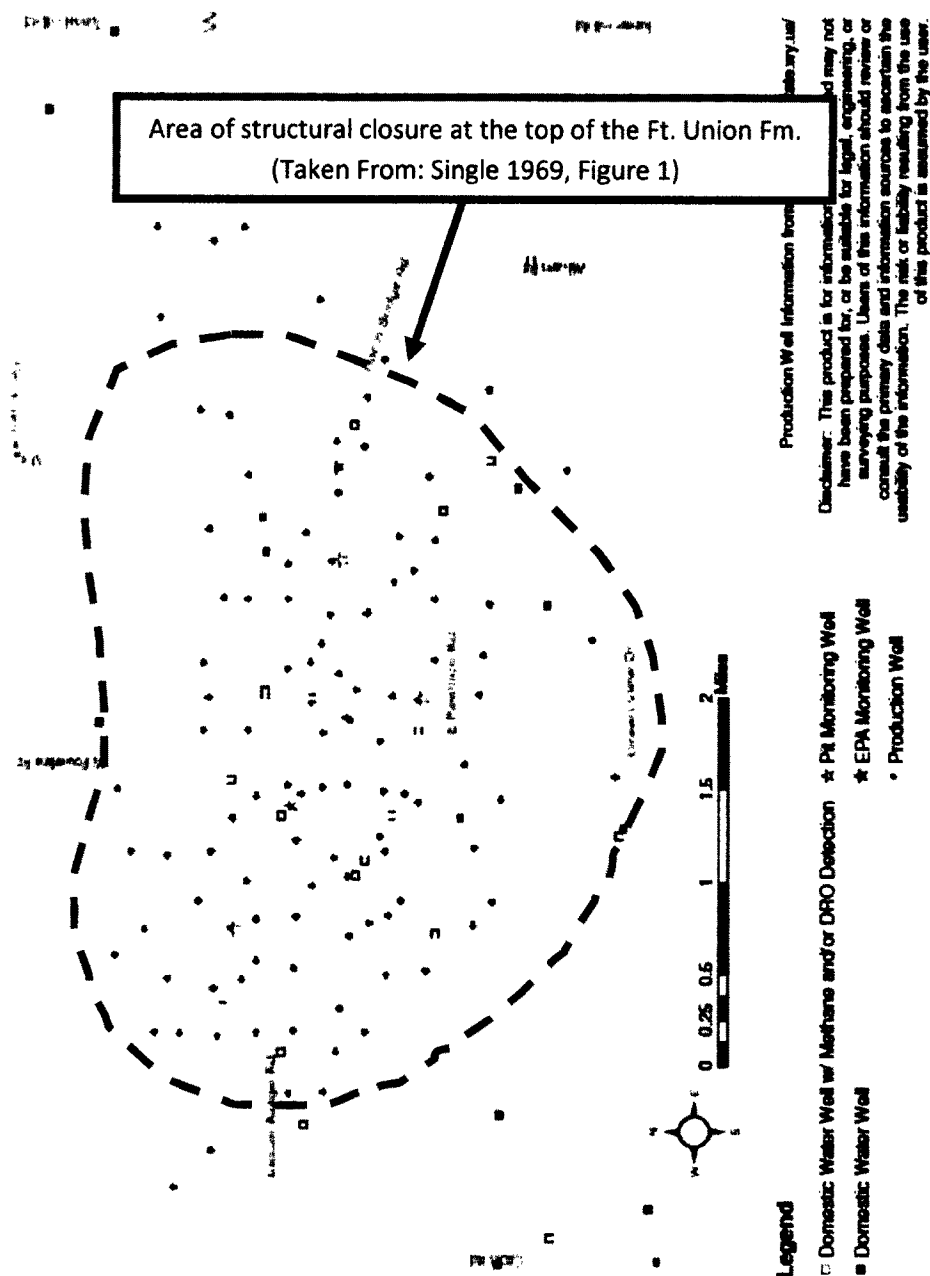
If only the domestic wells with more than 2 producing wells within 600 m are considered (Draft Report Figure 18(c) (Draft Report Pg. 28), there is a good correlation of increasing methane concentration with depth. The wells with more than 2 producing wells within 600 m are most likely to be located within the area of structural closure and therefore within the productive limits of the Pavillion Field anticlinal closure. It would be expected that methane concentrations would increase with depth for all wells drilled within the productive limits of Pavillion Field **Figure 5**.

Enhanced migration of hydrocarbons into shallow intervals and eventually to the surface would be expected above a subsurface hydrocarbon accumulation such as Pavillion Field. All petroleum basins exhibit some type of near-surface hydrocarbon leakage. In fact, a common exploration method involves the use of near surface soil geochemistry to detect and map traces of hydrocarbons which have managed to migrate into surface soil sediments after escaping from subsurface accumulations Jones and Drozd (1983). Studies have shown that the surface soil sediments above and around hydrocarbon accumulations are often enhanced in hydrocarbon content when compared to areas without subsurface hydrocarbon accumulations Kaluza and Saaed (1996).

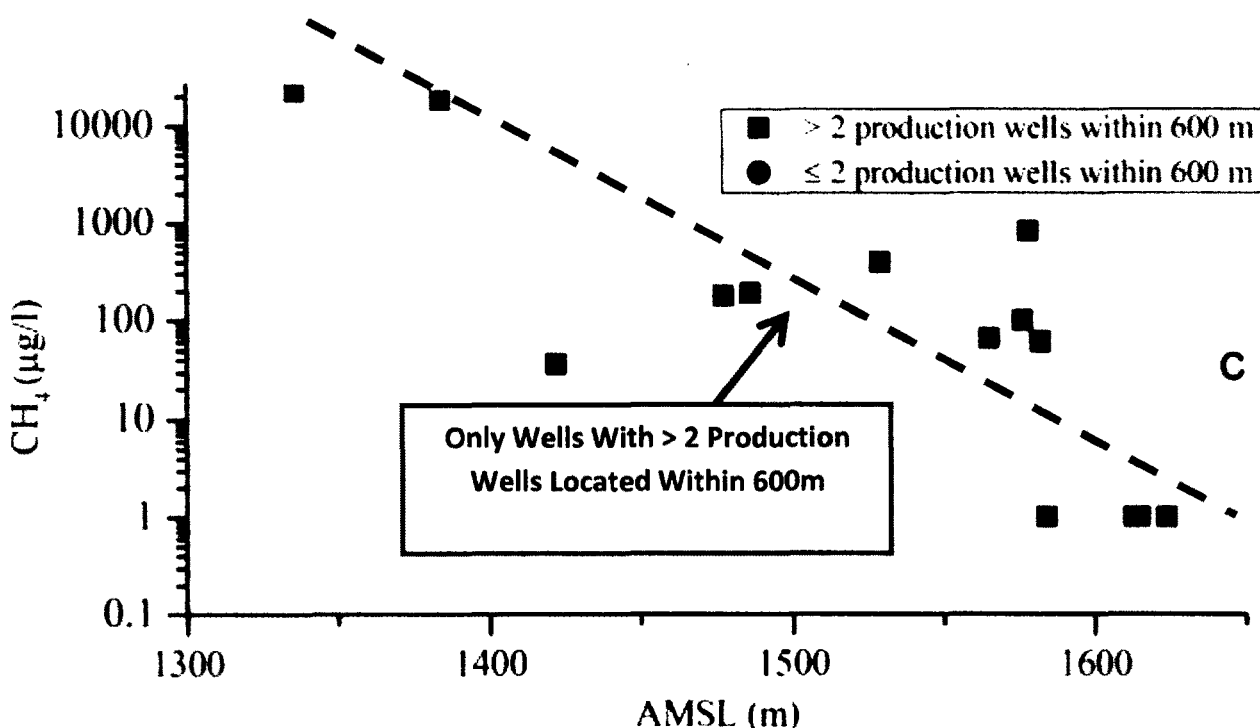


**Figure 3.)** Modified from Draft Report Figure 5, (Draft Report Pg. 6). In Pavillion Field, gas productive wells are concentrated in the area of anticlinal structural closure (taken from Single 1969, Figure 1) because this is the area where natural gas is trapped in several stratigraphic intervals. Domestic water wells located within the area of structural closure are likely to be located within 600 m of two or more gas productive wells. All stratigraphic intervals located within the area of structural closure are more likely to contain natural gas than correlative stratigraphic intervals located outside of the area of structural closure. Gore and Associates (2011) identified two areas with high quality water from deep wells in the vicinity of Pavillion Field. Both of these areas are located outside of the area of structural closure.

# Domestic Wells with Detections of Organics



**Figure 4.)** Modified from EPA (2011) Pg. 5. In Pavillion Field, gas productive wells are concentrated in the area of anticlinal structural closure (taken from Single 1969, Figure 1) because this is the area where natural gas is trapped in several stratigraphic intervals. Domestic water wells located within the area of structural closure are likely to be located within 600 m of two or more gas productive wells. All stratigraphic intervals located within the area of structural closure are more likely to contain natural gas than correlative stratigraphic intervals located outside of the area of structural closure.



**Figure 5.)** Modified from Draft Report Figure 18 (c) (Draft Report Pg. 28). If only the domestic wells with more than 2 producing wells within 600 m are considered, there is a good correlation of increasing methane concentration with depth. The wells with more than 2 producing wells within 600 m are most likely to be located within the area of structural closure and therefore within the productive limits of the Pavillion Field anticlinal closure. It would be expected that methane concentrations would increase with depth for all wells drilled within the productive limits of Pavillion Field.

9. Failure to recognize that cement bond/variable density logs run under non pressurized or "0 psi" conditions are unreliable and often pessimistic in evaluating actual cement effectiveness due to the presence of a microannulus.

An unspecified number of cement bond logs from the Pavillion Field area were evaluated by the EPA as part of the Draft Report (Draft Report Pg. 16). From this review five wells are specifically identified in the study as having "sporadic bonding outside production casing directly above intervals of hydraulic fracturing" (Draft Report Pg. 37-38):

- "Pavillion Fee 34-03B, a cement bond/variable density log conducted on 10/22/2004 indicated no cement until 2,750 ft. and sporadic bonding to 3,400 ft. below ground surface."
- "Tribal Pavillion 41-10, a cement bond/variable density log indicates sporadic bonding directly above the interval of hydraulic fracturing at 1,618 ft. below ground surface."

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Sean Kelly; March 8, 2012

- "A cement bond/variable density log conducted on Tribal Pavillion 24-02 after a squeeze job at the base of surface casing indicates sporadic bonding outside production casing below surface casing to the interval of hydraulic fracturing at 1,538 ft. below ground surface."
- "Tribal Pavillion 11-11B, a cement bond/variable density log indicates sporadic bonding between 1,000 to 1,650 ft. below ground surface with hydraulic fracturing occurring at 1,516 ft. below ground surface."

A common condition that results in the misinterpretation of cement bond/variable density logs is the development of a microannulus located between the production casing and cement sheath. The cement is not bonded to the production casing, but the production casing to borehole annulus is in fact effectively cemented and is sufficient to form a hydraulic seal and prevent fluid migration behind the casing under normal production conditions Bigelow (1990). A microannulus can produce "straight lining" of the variable density display and high amplitudes casing arrivals giving the false impression of indicating no cement (Boyd et. al 2006). It is recommended that operators run cement bond/variable density logs with pressure (1,000 to 1,500 psi) on the casing to identify and reduce or eliminate the effects of microannulus on the cement bond/variable density log readings Bigelow (1990) Boyd et al. (2006).

I was able to obtain cement bond/variable density logs online from the Wyoming Oil and Gas Conservation Commission for 10 of the 11 wells studied in my review of Pavillion Field wells. This compares to the EPA results of obtaining cement bond/variable density logs in "less than half of production wells" studied in the Draft Report (Draft Report Pg. 16).

Eight of the ten wells I studied clearly indicated that the cement bond/variable density logs were run under "0 psi" conditions on the log header. The remaining two wells indicated that the casing was filled to surface with fresh water on the log header. Cement bond/variable density logs run under "0 psi" conditions can result in a pessimistic evaluation of actual cement present in the casing to borehole annulus due to the presence of a microannulus Bigelow (1990) Boyd et al. (2006). Given that the casing for each well was likely filled with fresh water to the surface while running the cement bond/variable density logs, a casing pressure of 1,000 psi would not be obtained until a depth of 2,325' (1,000 psi/0.43 psi/ft.) and a casing pressure of 1,500 psi would not be obtained until a depth of 3,488' (1,500 psi/0.43 psi/ft.). The potential pessimistic effects of microannulus on cement bond/variable density logs cannot be ruled out on cement bond/variable density logs run above 3,488 ft. under "0 psi" conditions.

A review of the wells which were specifically identified as having "sporadic bonding outside production casing directly above intervals of hydraulic fracturing" (Draft Report Pg. 37-38): The Pavillion Fee 34-03B, Pavillion 41-10 and Pavillion 24-02 (second run) cement bond/variable density logs were run under "0 psi" conditions.

An interpretation of "sporadic bonding outside of production casing" on cement bond/variable density logs run under "0 psi" conditions should be considered suspect above depths of 3,488 ft. until the possibility of microannulus development can be eliminated by running the cement bond/variable density log under pressurized conditions of 1,000 to 1,500 psi.

**Finally, if the production casing to borehole annulus cement integrity was insufficient to contain the hydraulic fracture fluids injected into the perforated intervals allowing the hydraulic fracture fluids to migrate into shallower intervals through the production casing to borehole annulus as hypothesized by the Draft Report, then natural gas from the producing formations would also be expected to enter**

**into the production casing to borehole annulus after the producing well was completed and placed on production. The natural gas filling the production casing to borehole annulus would increase the pressure in the production casing to borehole annulus. The pressure of the production casing to borehole annulus is monitored by a dedicated pressure gauge and could easily be checked by the operator and verified by the EPA. The presence of natural gas and increased pressure in the production casing to borehole annulus would be a direct indication of insufficient cement quality above the completion intervals. This should have been investigated by the EPA.**

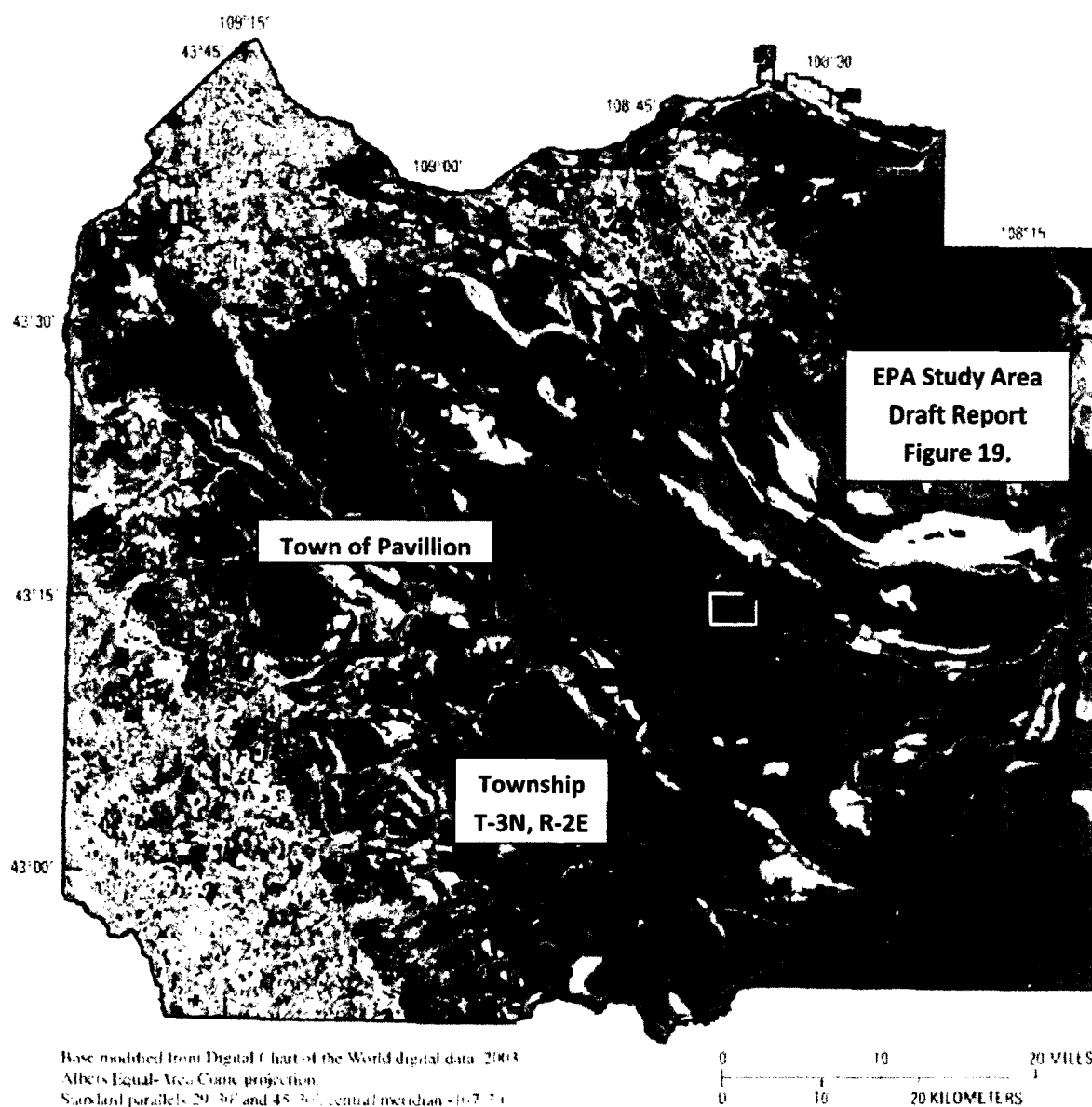
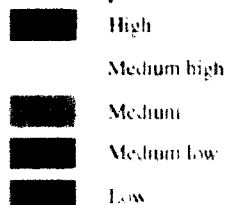
10. Failure to thoroughly investigate potential causes of contamination other than oil and gas operations. Mason et al. (2005) generated a regional map showing surficial aquifer sensitivity to surface contamination as part of their study **Figure 6**. The parameters used to identify an area's sensitivity to contamination included: depth to initial ground water, hydrogeologic setting, soil characteristics, aquifer recharge, land surface slope and vadose zone properties. Almost all of Township T-3N, R-2E which includes the Town of Pavillion and the study area for the Draft Report is identified as having high aquifer sensitivity to surface contamination **Figure 6**.

Mason et al. (2005) also compiled and mapped all known sites with potential ground water contaminant sources and all sites known to have ground water contamination based on the Wyoming Department of Environmental Quality's 1998 Wyoming Pollution Point Source database **Figure 7**. The sites with potential ground water contaminant sources includes: the locations of non-leaking underground storage tanks, above-ground storage tanks and municipal landfills. The sites with known ground water contamination includes: the locations of leaking underground storage tanks and ground water pollution control areas Mason et al. (2005). At least six locations with either potential or known ground water contamination were identified in Township T-3N, R-2E as of 1998 **Figure 7**.

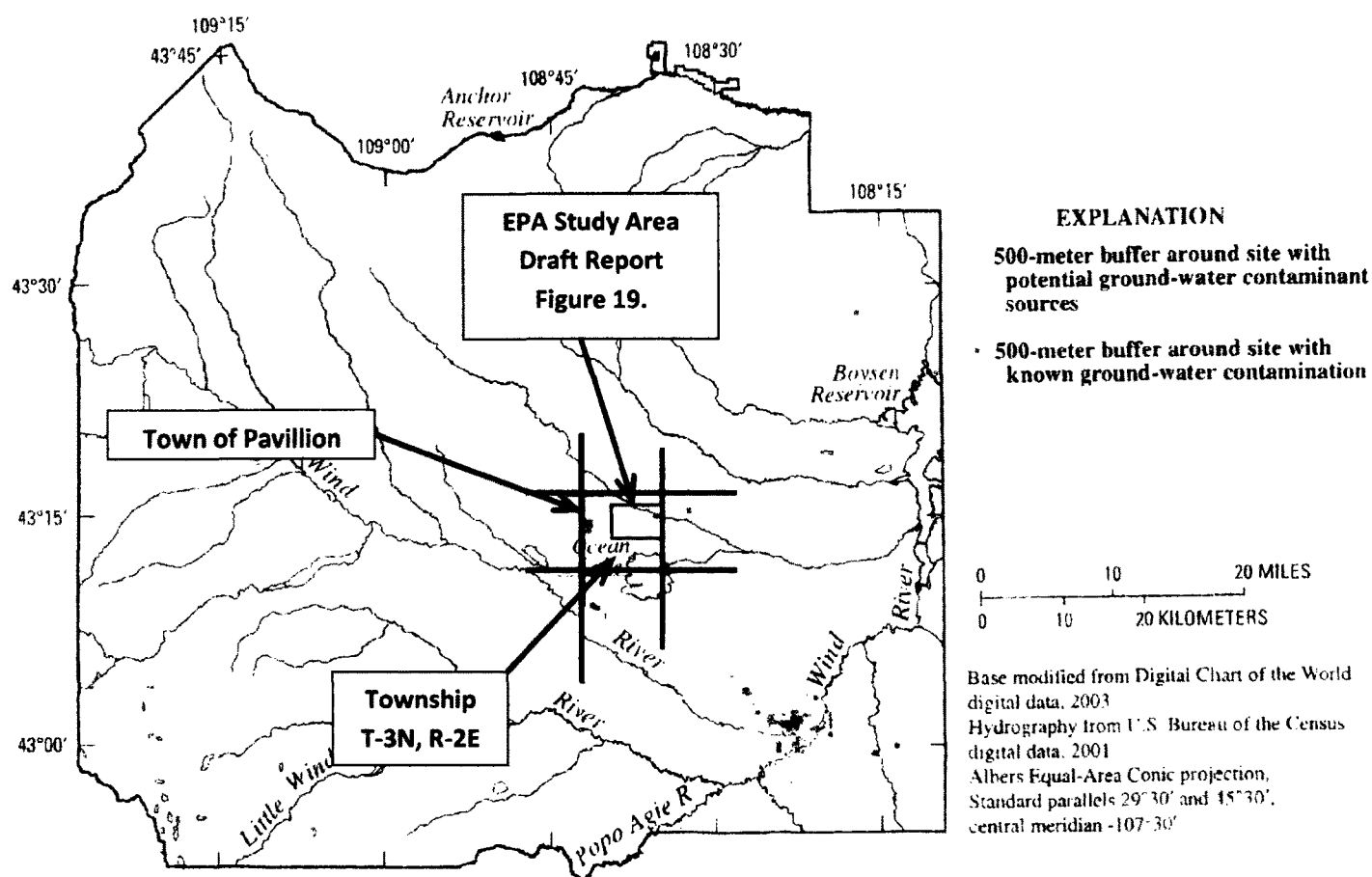
Mason et al. (2005) also identified and mapped all known locations of National Pollution Discharge Elimination points based on the Wind River Environmental Quality Commission database **Figure 8**. At least one National Pollution Discharge Elimination System site location was identified in Township T-3N, R-2E as of 1998 **Figure 8**.

Other potential sources of contamination that should be investigate include rural septic sytems, abandoned machinery, trash piles and the disposal of domestic and "mechanic shop" waste products. Contamination from these sources could have a significant local impact on the "taste and odor" of the water produced from domestic ground water wells that are completed in unconfined aquifers at very shallow depths (<50') and located in areas with high sensitivity to surface contamination, such as PDGW05.

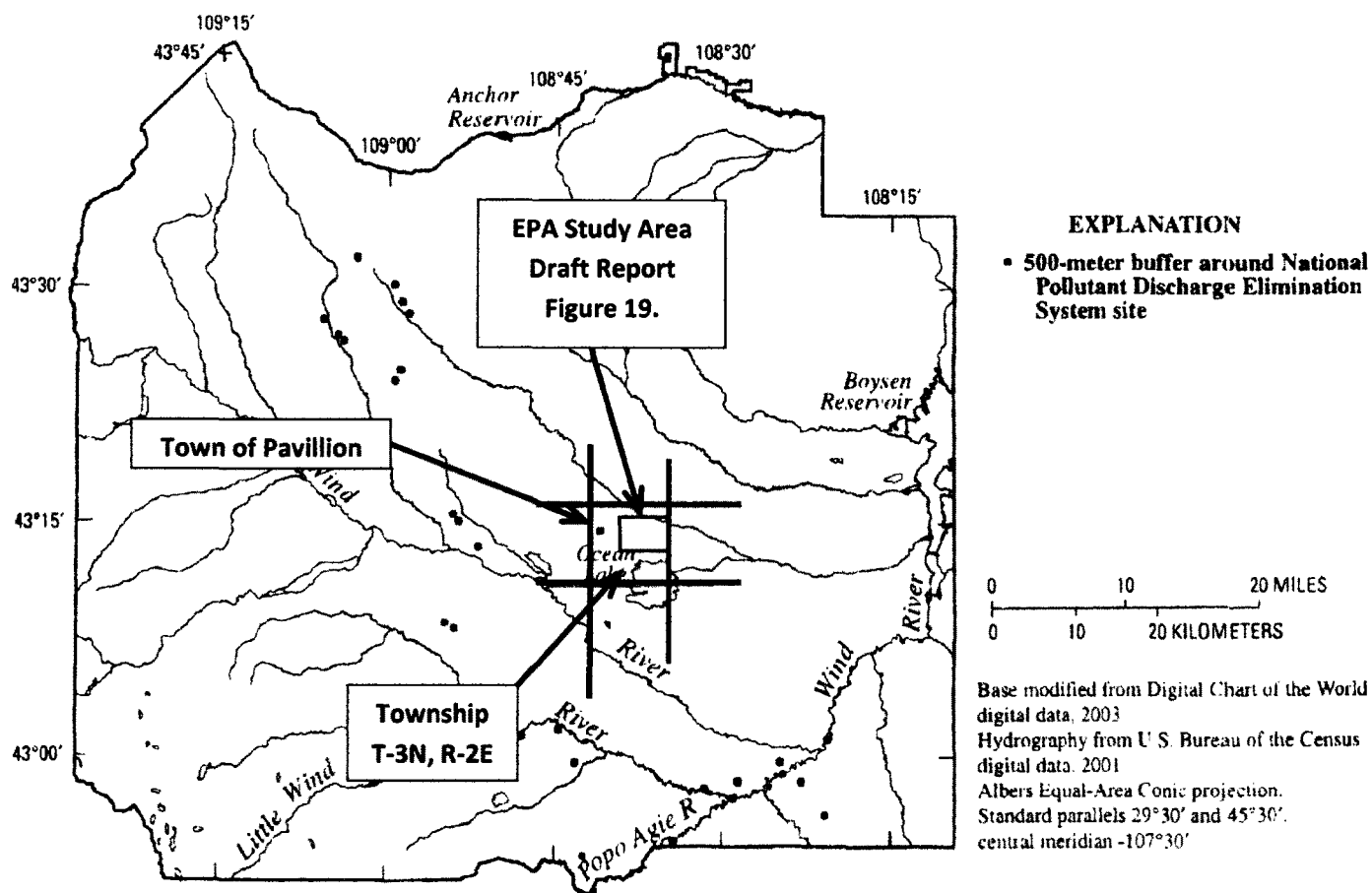
The impact of decades of farming and irrigation on the quality of water produced from shallow unconfined aquifers also should not be overlooked. Irrigation practices which produce changes in infiltration rates and changes in the sources of recharge water and recharge pathways, combined with the use of fertilizers and pesticides can also have a significant impact over a large area on ground water chemistry and ground water "taste and odor".

**EXPLANATION****Aquifer sensitivity to surface contamination**

**Figure 6.)** Modified from Mason et al. 2005 Figure 7. Almost all of Township T-3N, R-2E which includes the Town of Pavillion and the study area for the Draft Report is identified as having high aquifer sensitivity to surface contamination.



**Figure7.)** Modified from Mason et al. 2005 Figure 9. At least six locations with either potential or known ground water contamination were identified in Township T-3N, R-2E as of 1998.



**Figure 8.)** Modified from Mason et al. 2005 Figure 10. At least one National Pollution Discharge Elimination System site location had been identified in Township T-3N, R-2E as of 1998.

**11. Failure to conduct a true scientific investigation based on the scientific method.**

The scientific method requires first making unbiased observations, then formulating a series of questions based on the observations, followed by formulating hypotheses and then testing the various hypotheses by experimentation and additional unbiased observations. Rather than follow the scientific method, the EPA has evoked a "multiple lines of reasoning approach" (Draft Report Pg. xi-xii) in an attempt to force a flawed processes and invalid data to fit what appears to be a predetermined, outcome driven conclusion.

The EPA Draft Report takes several shortcuts by not considering the geology of the Pavillion area, by not documenting and analyzing specific well and specific stratigraphic completions, by not collecting stabilized representative data and by not peer reviewing the Draft Report. Why did the EPA rush to release this Draft Report in its present form and make such a big deal out of it in the media? The quality of this investigation and subsequent report is substandard compared to other studies generated by the agency.

**Questionable Portions of the Draft Report to be Challenged, Re-Examined or Requiring Additional****Explanation:**

1. *"The Wind River Formation is the principal source of domestic, municipal and stock (ranch, agricultural) water in the area of Pavillion and meets the Agency's definition of an Underground Source of Drinking Water" (Draft Report Pg. xi).*

I agree that the upper Wind River Formation aquifers do meet the EPA definition of an Underground Source of Drinking Water (USDW) under the United States Code of Federal Regulations, Title 40, Section 144.3. However, the lower Wind River Formation aquifers below the lower laterally continuous intermediate seal (**Sean Kelly Attachment No.3**) in the Pavillion Field area should be exempt from USDW classification based on contamination levels of naturally occurring hydrocarbons contained in these aquifers: United States Code of Federal Regulations, Title 40, Section 146.4. "Ground water contamination with constituents such as those found at Pavillion is typically infeasible or too expensive to remediate or restore (GAO 1989)" (Draft Report Pg. 39).

2. *"Domestic and stock wells in the area are screened as deep as 244 meters below ground surface" (Draft Report Pg. xi).*

Where are the locations of these deep domestic and stock wells, and where are they located in relation to the area of upper Wind River structural closure? These locations should be identified on a map.

3. *"At least 33 surface pits previously used for the storage/disposal of drilling wastes and produced and flowback waters are present in the area" (Draft Report Pg. xi).*

If the locations of these 33 pits have been identified, then where are the locations of these 33 pits? How do these pit locations relate to the two deep EPA monitor well locations? How do these pit locations relate to domestic ground water well locations? In what direction are the contaminants potentially moving? These locations and potential flow directions need to be identified on a map. This is the type of information that would actually be of use to the residents of the area.

4. *"Detections of elevated levels of methane and diesel range organics (DRO) in deep domestic wells prompted the Agency to install 2 deep monitoring wells" (Draft Report Pg. xi).*

Where are the locations of these deep domestic wells, and where are they located in relation to the area of upper Wind River structural closure? These locations need to be identified on a map.

5. *"Determination of the sources of inorganic and organic geochemical anomalies in deeper ground water was considerably more complex than determination of sources in shallow media necessitating the use of multiple lines of reasoning approach common to complex scientific investigations" (Draft Report Pg. xi-xii).*

The word "multiple" is misspelled. In my opinion, I do not think the use of "multiple lines of reasoning approach" is actually common to many scientific investigations. Please provide references to the

scientific acceptance and scientific legitimacy of the “multiple lines of reasoning approach” used as the basis for reaching the final conclusions in this study.

6. *“However, there are flowing conditions in a number of deep stock wells suggesting that upward gradients exist in the area of investigation” (Draft Report Pg. xiii).*

Where are the locations of these deep stock wells with flowing conditions? How many actually exist? These locations should be identified on a map. To determine if an “upward gradient” exists in the area, a much more thorough and rigorous hydrodynamic investigation must be performed by the EPA. Hydrological analyses and interpretations are almost entirely lacking in the Draft Report. To analyze fluid flow directions, the potentiometric gradient in an area must be determined, this is usually accomplished by generating a potentiometric surface elevation map. The presence of “flowing conditions” indicates the aquifer’s potentiometric surface is above ground level at these locations (wherever they are located). Both deep EPA monitor wells had potentiometric surfaces well below ground level at their locations (April 2011 water levels). Assuming the deep stock wells and the deep EPA monitor wells are in hydrodynamic communication (this is impossible to determine because the deep stock wells are not specifically identified), then flow would actually be away from the stock wells with the higher potentiometric elevations and towards the deep EPA monitor wells with the lower potentiometric elevations. In this case, the potentiometric surface and the gradient would actually be downward, not upward as indicated in several places in the Draft Report.

7. *“Alternative explanations were carefully considered to explain individual sets of data.” (Draft Report Pg. xiii).*

Alternative explanations are given brief mention only in the Draft Report Conclusions (Draft Report Pg. 33-39) and are barely mentioned in the Methods or Results and Discussion portions of the Draft Report. In my opinion, this does not constitute “carefully considered”. In my review of the Draft Report the EPA did not give nearly enough consideration to the petroleum and hydrological systems to fully appreciate the probability of almost all of their observations resulting from the natural geology and hydrogeology of the region. Instead the Draft Report focused on forcing invalid, questionable, non-stabilized and non-representative water sampling data to fit a preconceived conclusion that has little if any basis in the geology or hydrogeology of the area.

8. *“For instance, at one production well, the cement bond/variable density log indicates no cement until 671 m below ground surface. Hydraulic fracturing occurred above this depth at nearby production wells.” (Draft Report Pg. xiii).*

Where is the location of the well with no cement until 671 m, and where are the wells where hydraulic fracturing occurred above this depth? These locations should be identified on a map.

9. *“A similar lines of reasoning approach was utilized to evaluate the presence of gas in monitoring and domestic wells. A comparison of gas composition and stable carbon isotope values indicate that gas in*

*production and monitor wells is of similar thermogenic origin and has undergone little or no degradation. A similar evaluation in domestic wells suggests the presence of gas of thermogenic origin undergoing biodegradation. This observation is consistent with a pattern of dispersion and degradation with upward migration observed for organic compounds.” (Draft Report Pg. xiii).*

This is a conclusion the EPA is correct on. The natural gas observed in gas production wells, the two deep EPA monitor wells and some domestic water wells is all derived from a common thermogenic source. This thermogenically derived natural gas has migrated vertically over time through natural buoyant processes without the presence of 1.) producing wellbores, 2.) “hydraulic fracture stimulation fluid excursion” or 3.) new fractures generated during the hydraulic fracture stimulation process. Biodegradation would be expected to occur as natural gas migrated into and through shallower intervals.

10. *“Again, with the exception of two producing wells, surface casing of gas producing wells do not extend below the maximum depth of domestic wells in the area of investigation.” (Draft Report Pg. xiii).*

Again, what is the maximum depth of domestic wells in the area of investigation and where are these wells located? These locations should be identified on a map.

11. *“Again, alternate explanations of data have been considered. Although some natural migration of gas would be expected above a gas field such as Pavillion, data suggest that enhanced migration of gas has occurred within ground water at depths used for domestic water supply and to domestic wells.” (Draft Report Pg. xiii).*

Again, what alternate explanations were considered by the EPA in this report? Is the EPA suggesting it is impossible for natural gas to migrate under natural conditions from its thermogenic source into shallower strata and eventually to the surface? Of course the concentrations of natural gas are enhanced over all stratigraphic levels of Pavillion Field, Pavillion Field is a natural gas field!

12. *Location map, Figure 1. (Draft Report Pg. 1).*

Please provide the basic information needed to locate the study area such as county outlines and names, and label the townships.

13. *“A review of production well records obtained on line from WOGCC indicates that hydraulic fracturing in gas production wells occurred as shallow as 372 m (1,220’) below ground surface with associated surface casing in production wells as shallow as 110 m (361’) bgs.” (Draft Report Pg. 2).*

The Draft Report needs to identify this well and its location.

14. *"Information obtained from the Wyoming State Engineer's Office and homeowners indicates that domestic wells (including stock wells) in the area of investigation are screened as deep as 244 m (800') bgs."*

Where are the locations of these deep domestic wells, and where are they located in relation to the area of upper Wind River structural closure? These locations need to be identified on a map. How many deep domestic wells actually exist in the immediate area?

15. *"The Wind River Formation meets the definition of an Underground Source of Drinking Water (USDW) under the United States Code of Federal Regulations, Title 40, Section 144.3." (Draft Report Pg. 4).*

The shallow portions of the Wind River Formation (above the lower laterally continuous intermediate seal, Sean Kelly Attachment No.3) may meet the definition of an USDW. The middle and deeper portions of the Wind River Formation below the laterally continuous intermediate seal (**Sean Kelly Attachment No.3**) in the area of the Pavillion natural gas field should be exempt from USDW classification based on contamination levels of naturally occurring hydrocarbons: United States Code of Federal Regulations, Title 40, Section 146.4. "Ground water contamination with constituents such as those found at Pavillion is typically infeasible or too expensive to remediate or restore (GAO 1989)" (Draft Report Pg. 39).

16. *"Both deep monitoring wells were located away from gas producing wells, known locations of pits, and areas of domestic waste disposal (abandoned machinery)." (Draft Report Pg. 5).*

Please explain the distance and type of equipment which appears to be the type of equipment normally associated with gas producing wells observed in the background of Draft Report Figure C-11 and Draft Report Figure D-5. This appears to be a well pad with separators and tankage associated with a gas production well suggesting the two deep EPA monitor wells may not be located "away from gas production wells, known locations of pits, and areas of domestic waste disposal (abandoned machinery)".

17. *"because large volumes of ground water were extracted from the wells during development and prior to sampling, it is unlikely that ground water chemistry was impacted by drilling additives." (draft Report Pg. 7).*

What specifically are considered "large volumes of ground water"? How does this "large volume" compare to the fluids lost during the drilling of the deep EPA monitor wells?

18. *"Locations of both MW01 and MW02 were in fields used for alfalfa hay production away from production wells, pads, and pits". (Draft Report Pg. 8).*

Please explain the distance to and the type of equipment observed in the background of Draft Report Figure C-11 and Draft Report Figure D-5. This appears to be a well pad with separators and tankage

associated with a gas production well suggesting the two deep EPA monitor wells may not be located "away from production wells, pads and pits".

19. *"Examination of resistivity and cuttings indicated elevated resistivity at depths where white coarse-grained sandstone was observed. This relationship was utilized to place screens at both deep monitoring wells at the deepest observed interval of white coarse-grained sand (Figure 7)." (Draft Report Pg. 11).*

A more accurate identification of sandstone prone intervals in the two deep EPA monitor wells would have been obtained if the EPA would have utilized the natural gamma ray and density data in addition to the resistivity data to determine screen placement. The EPA must have been aware that they were placing the screened interval in the Randall MW01 monitor well at depth with the potential for significant natural gas concentrations based on the mud log shows obtained while drilling the well. See Figure 2.

20. *"The wells were purged at a flow rate of approximately 5 to 30 L/min." (Draft Report Pg. 11).*

"Approximately 5 to 30 L/min" is a significant range. Which well? When? Much more specific, detailed and accurate purge data needs to be provided to determine if the two deep monitor wells were correctly purged.

21. *"Purge volumes prior to sampling ranged from about 200 to 450 L (Phase III) and 1100 to 1250 L (Phase IV)." (Draft Report Pg. 11).*

"About 200 to 450 L (Phase III) and 1100 to 1250 L (Phase IV)" is a significant range. Which well? When? Much more specific, detailed and accurate purge data needs to be provided to determine if the two deep monitor wells were correctly purged. 200 to 450 L??? These are very small purge volumes.

22. On Draft Report Pages 11-12 the word "approximately" is way overused. What is approximate about these values: "approximately 5 to 30 L/min", "approximately 27.6 L/min", "approximately 24.2 L/min", "approximately 18.2 m", "approximately 0.6 m", "approximately 1117 L", "approximately 18.9 L/min", "approximately 1249 L", "approximately 1287 L" and "approximately 10 min"? The "approximate" values seem to be either a range of values or an exact value.

23. *"Specific conductance readings were typically variable, likely due to continuous off-gassing and bubble formation within the conductivity sensor." (Draft Report Pg. 12).*

A more likely explanation is that the aquifer has not stabilized with respect to the monitor well, and the water samples are not yet representative of the aquifer water. More purging is required for the aquifer to reach equilibrium with the well so that representative water samples may be collected.

24. *Draft Report Figure 9. (Draft Report Pg. 13).*

Draft Report Figure 9, shows the flow-cell readings as a function of elapsed time for deep EPA Monitor well MW02, Phase IV sampling. Where is similar data presented for both deep EPA monitor wells during Phase III sampling and MW01 Phase IV sampling? On DRAFT Report Figure 9, the specific conductance values are still variable, and the oxidation-reduction potential is still declining with elapsed time. Both of these readings are indications that the aquifer has not stabilized with respect to the monitor well, and the water samples are not yet representative of the aquifer water. More purging is required for the aquifer to reach equilibrium with the well so that representative water samples may be collected. Also, since the rate of water production from the monitor wells was not constant and in fact declined from the purging phase through the sampling phases it would be much more meaningful to plot the variables in Draft Report Figure 9 as a function of cumulative water produced, NOT as a function of elapsed time. Plotting the variables as a function of cumulative water produced would likely show additional evidence that the aquifer has not stabilized with respect to the monitor well, and the water samples are not yet representative of the aquifer water.

25. *"The lower reproducibility for these compounds detected in MW02 is likely due to difficulties in sampling and preserving water that is oversaturated in gas." (Draft Report Pg. 14).*

A more likely explanation is that the aquifer has not stabilized with respect to the monitor well, and the water samples are not yet representative of the aquifer water. More purging is required for the aquifer to reach equilibrium with the well so that representative water samples may be collected.

26. *"Borehole geophysical logs available on line from WOGCC were utilized to map lithology in the area of investigation." (Draft Report Pg. 15).*

Where are these maps presented?

27. *"Log resolution was sufficient to discern distinct layers of shale 1 m or greater in thickness but not sufficient to differentiate coarse-, medium-, and fine-grained sandstones, nor sandstones containing various proportions of shale." (Draft Report Pg. 15).*

It is possible and a common petrophysical procedure to calculate the volume of shale in a sandstone shale sequence by simply utilizing the natural gamma ray log or in more complex calculations by utilizing a combination of the natural gamma ray log and the compensated neutron log. See **Sean Kelly-Attachment No.2** and **Sean Kelly-Attachment No.3** for examples where the gamma ray log data has been used to make an estimate of the volume of shale present in the upper Wind River Formation.

28. *"Cement bond/variable density (CBL/VDL) logs, available for less than half of production wells, were obtained on line from WOGCC to evaluate well integrity." (Draft Report Pg. 16).*

During my research, I was able to obtain CBL/VDL logs on line from the WOGCC for 10 out of the 11 wells I evaluated. Why were the EPA results so much lower?

29. *"Communication of fluids between intervals has been observed to occur despite indication of "good to excellent" cement bond on acoustic logs (Boyd et al. 2006)." (Draft Report Pg. 16).*

The EPA has taken liberties with this reference. A closer review of the Boyd et al. 2006 paper shows that mechanical isolation existed between the zones with "good to excellent cement bond" prior to an acid treatment being performed (Boyd et al. 2006 Pg. 3). No injectivity/communication was observed while testing with brine, injectivity/communication was only observed after the intervals were treated with acid. It is speculated in that an acid treatment consisting of 15% HCl designed to improve injectivity either damaged the cement or created channels through the easily dissolved calcium carbonate mudcake (Boyd et al. 2006 Pg. 3). Acid treatments are not common in the Pavillion Field completions based on my observations.

30. *"There are at least 33 pits previously used for the storage/disposal of drilling wastes, produced water, and flowback fluids in the area of investigation" (Draft Report Pg. 17).*

If the locations of these 33 pits have been identified, then where are the locations of these 33 pits? These pits seem to be the primary cause of contamination which could potentially have an adverse effect on domestic water wells. These pit locations need to be identified on a map.

31. *"The geochemistry of ground water from the deep monitoring wells is distinctive from that in the domestic wells." Draft Report Pg. 19).*

This would be expected, particularly since the aquifers that the two deep EPA monitor wells are completed in are not in hydrodynamic communication with the aquifers that most of the domestic wells are completed in. Water wells completed in the Wind River Formation yield water from both unconfined and confined sandstone layers. Wells less than 90' deep usually yield water from unconfined sandstone layers recharged primarily by water from overlying Quaternary deposits and irrigation return flow. Wells completed in the Wind River Formation more than 100' deep usually yield ground water from confined sandstone layers. These confined aquifers are recharged by surface waters or by infiltration from precipitation (Daddow, 1996). Finally, the geochemistry in the shallow aquifers has been significantly altered from decades of farming and irrigation and is no longer representative of original aquifer geochemistry so a comparison of present day shallow domestic aquifer geochemistry to the deep aquifer geochemistry is meaningless.

32. *"Chloride enrichment in this well is significant because regional anion trends tend to show decreasing Cl concentrations with depth." (Draft Report Pg. 19).*

Where is the data to support the statement "regional anion trends show decreasing Cl concentrations with depth"? It is well documented that in general, TDS and Cl<sup>-</sup> concentrations increase with depth in

most sedimentary basins, particularly as ground water temperatures and their ability to dissolve solids increase with depth. Mason et al. 2005 (Pg.4) states that at depths of greater than a few thousand feet in the Wind River Basin, it is likely that the water from Tertiary aquifers is highly saline (dissolved-solids concentrations between 10,000 and 35,000 mg/L) to briny (dissolved-solids concentrations greater than 35,000 mg/L).

33. *"Prolonged purging did not show decreasing pH trends" (Draft Report Pg. 20).*

How long and what volume of water constitutes "prolonged purging"? How does the EPA explain the decrease in pH values observed in both deep EPA monitor wells between Sampling Phase III and Sampling Phase IV? Would additional purging result in further reductions in pH levels?

34. *"The monitoring wells produce ground water near-saturated in methane at ambient pressure, with concentrations up to 19.0 mg/L."*

This should be expected. The monitor wells were drilled to depths below a laterally continuous intermediate seal in an area of structural closure where thermogenic hydrocarbons generated deeper in the basin are migrating and being trapped forming a commercial natural gas accumulation (**Sean Kelly –Attachment No.3**). Other wells in the area encountered sandstone intervals at similar depths which likely contain free natural gas in addition to methane saturated in water. The Encana Pavillion Fee 11-11B has an interval at 565-573' where the open-hole logs have deep resistivity in excess of 100 ohm-m, resistivity invasion profiles indicating good permeability and porosity in excess of 24% with strong "gas effect" on the neutron-density porosity (**Sean Kelly-Attachment No.3**). The Tom Brown Pavillion Fee 41-10 has an interval at 541-551' where the open-hole logs have deep resistivity of 40-65 ohm-m, resistivity invasion profiles indicating good permeability and 26% porosity with strong "gas effect" on the neutron-density porosity (**Sean Kelly-Attachment No.3**).

35. *"Detections of organic chemicals are more numerous and exhibit higher concentrations in the deeper of the two monitoring wells (Figure 17, Table 3). This observation, along with trends in methane, potassium, chloride, and pH, suggest a deep source (>299 m bgs)."( Draft Report Pg. 23).*

This is another observation and conclusion with which I agree. The source of the contamination is deep (>299 m bgs). The source of the contamination originates from organic rich rocks with relatively high natural concentrations of total organic carbon (usually shale intervals) which have been buried deep enough in the basin to where the increased temperatures have converted the total organic carbon contained in these "source rocks" into hydrocarbons. The hydrocarbons migrate out of the area where they are generated (could be distances of 10's of miles) through natural buoyant processes until they either reach the surface where they dissipate into the atmosphere or until they reach an area where they are trapped in subsurface strata. If enough hydrocarbons are trapped in a given area they can form an economic hydrocarbon accumulation such as the one located at Pavillion Field.

36. *Draft Report Table 3. (Draft Report Pg. 24). "Table 3. Geochemical impacts in deep ground-water monitoring wells"*

The use of the word "impacts" implies that a conclusion has been reached without first considering the data. It would have been "more scientifically correct" to label Table 3 as "Ground water geochemical data obtained from the two deep EPA monitor wells."

37. *Draft Report Table 4. (Draft Report Pg. 26).*

Please explain the meaning of all the different percentages in Table 4, and used throughout the Draft Report. Are they the percentage of overall stimulations which used the compounds? Are they the percentage of compounds used in a given component used in a well stimulation? Are they the volume percentage of a compound in a given well stimulation? This is really unclear to the reader and needs to be clarified by the EPA.

38. *"Gas from the Fort Union and lower Wind River Formations is generally dry and unlikely to yield liquid condensates at ground water temperatures and pressures." (Draft Report Pg. 27).*

Did the EPA consider the possibility that the gas produced from the Fort Union and Wind River formations may have been capable of producing liquid condensates at temperatures and pressure conditions greater (at deeper burial depths) than ground water temperatures and pressures? The general trend of hydrocarbon gas migration from depth is for the hydrocarbon gases to expel high molecular weight compounds to a liquid phase resulting in a gas which is less dense (England et al. 1987). Once generated these liquid hydrocarbons could theoretically migrate along the same migration pathways as the natural gas resulting in minor concentrations of heavier hydrocarbons in ground water. The natural gas present at Pavillion Field was generated in deeper thermally mature portions of the basin under higher temperatures, and has migrated into the Shallow Pavillion Field trap.

39. *"yet the compositions and concentrations of organic compounds detected in these wells (the two deep EPA monitor wells) are quite different (Figure 17) further suggesting a deep source of BTEX in MW02." (Draft Report Pg. 27).*

Once again, the EPA is correct, the source of the BTEX detected in the two deep EPA monitor wells is a deep source. The organic compounds were generated by natural process in the petroleum system. The fact that there is variation in concentrations of organic compounds is not unusual. It is common to observe variations in condensate yields and condensate compositions from producing well to producing well particularly when the wells are completed in different stratigraphic intervals. The Randall MW01 and Locker MW02 are screened in different stratigraphic intervals (Sean Kelly-Attachment No.2 and Sean Kelly-Attachment No.3). This also assumes the two monitor wells have reached equilibrium with the aquifers and are producing stabilized and representative water samples, an assumption that is not apparent from the data presented in the Draft Report. Please provide the scientific definition of "quite different".

40. *Draft Report Figure 19. (Draft Report Pg. 30).*

Producing well 41-11 (API No. 49-013-21866) is shown to be included in cross section A-A'. Producing well 41-11 is not included on cross section A-A'. Was producing well 41-11 dropped from cross section A-A' because it was not hydraulic fracture stimulated, but was only acidized instead? The scale for the map on Draft Report Figure 19 is also wrong. The section lines on the base map are one mile in length which is equal to 1,610 m. When the length of a section line is compared to the map scale, the length of the section line exceeds the length of the 2,000 m scale.

41. *Draft Report Figure 20. (Draft Report Pg. 31).*

Is this a structural or a stratigraphic cross section? On what basis was sandstone differentiated from shale on this cross section?

42. *"In all three transport pathways, a general correlation (spatial relationships ultimately determined by fault and fracture systems in addition to lithology) would exist between proximity to gas production wells and concentration of aqueous and gas phase constituents in ground water." (Draft Report Pg. 32).*

What??? This statement makes absolutely no sense? I strongly recommend the following well documented references on hydrocarbon migration and entrapment: England and Mann et al. (1991), England (1994), Matthews (1996), Palciauskas (1991) and Schowalter (1979).

43. *"For instance, Osborne et al. (2011) observed a correlation between methane concentrations and proximity to hydraulically fractured gas production wells at locations above the Marcellus and Utica formations in Pennsylvania and New York." (Draft Report Pg. 31).*

Subsequent research utilizing microseismic technology and isotopic data now indicates that the natural gas observed in domestic ground water wells is in fact not related to natural gas development in the Marcellus Shale, but is naturally occurring. Schon (2011) presented evidence based on microseismic that even the longest fractures generated by the hydraulic fracture stimulation process in the Marcellus Shale do not reach the depths of potential domestic ground water. Davies (2011) raised serious questions about any links between hydraulic fracture stimulation in the Marcellus Shale and methane concentrations in domestic ground water. Baldassare et al. (2012) utilized isotopic data to show that "microbial, thermogenic and mixed microbial/thermogenic natural gas occurred in the aquifers pre-contemporary Marcellus Formation well drilling". Osborne et al. (2011) admits: "Distinguishing between methane in Marcellus shale (and other middle Devonian strata) from the methane found in shallower upper Devonian layers is currently difficult because of a lack of  $^{13}\text{C}$  and  $^2\text{H}$  data with depth". Molofsky et al. (2012) utilized  $^{13}\text{C}$  and  $^2\text{H}$  methane isotope data from different stratigraphic depths to prove that the methane found in domestic ground water wells is sourced from shallow upper Devonian age formations and is not related to or sourced from the deeper middle Devonian Marcellus Shale.

44. *"Reduced mass flux to the near surface environment and subsequent degradation along vertical and lateral transport pathways would explain lack of detection in domestic wells of compounds observed in MW02." (Draft Report Pg. 31).*

What??? This is another statement that makes absolutely no sense? I strongly recommend the following well documented references on hydrocarbon migration and entrapment: England and Mann et al. (1991), England (1994), Matthews (1996), Palciauskas (1991) and Schowalter (1979).

45. *"Migration of gas via wellbores having no cement or poor cement bonding outside production casing is well documented in the literature." (Draft Report Pg. 38).*

Please provide the specific "well documented" literature sources.

46. *"Finally, this investigation supports recommendations made by the U.S. Department of Energy Panel on the need for collection of baseline data, greater transparency on chemical composition of hydraulic fracturing fluids, greater emphasis on well construction and integrity requirements and testing. As stated by the panel, implementation of these recommendations would decrease the likelihood of impact to ground water and increase public confidence in the technology." (Draft Report Pg. 39).*

**I also agree with and support these statements.**

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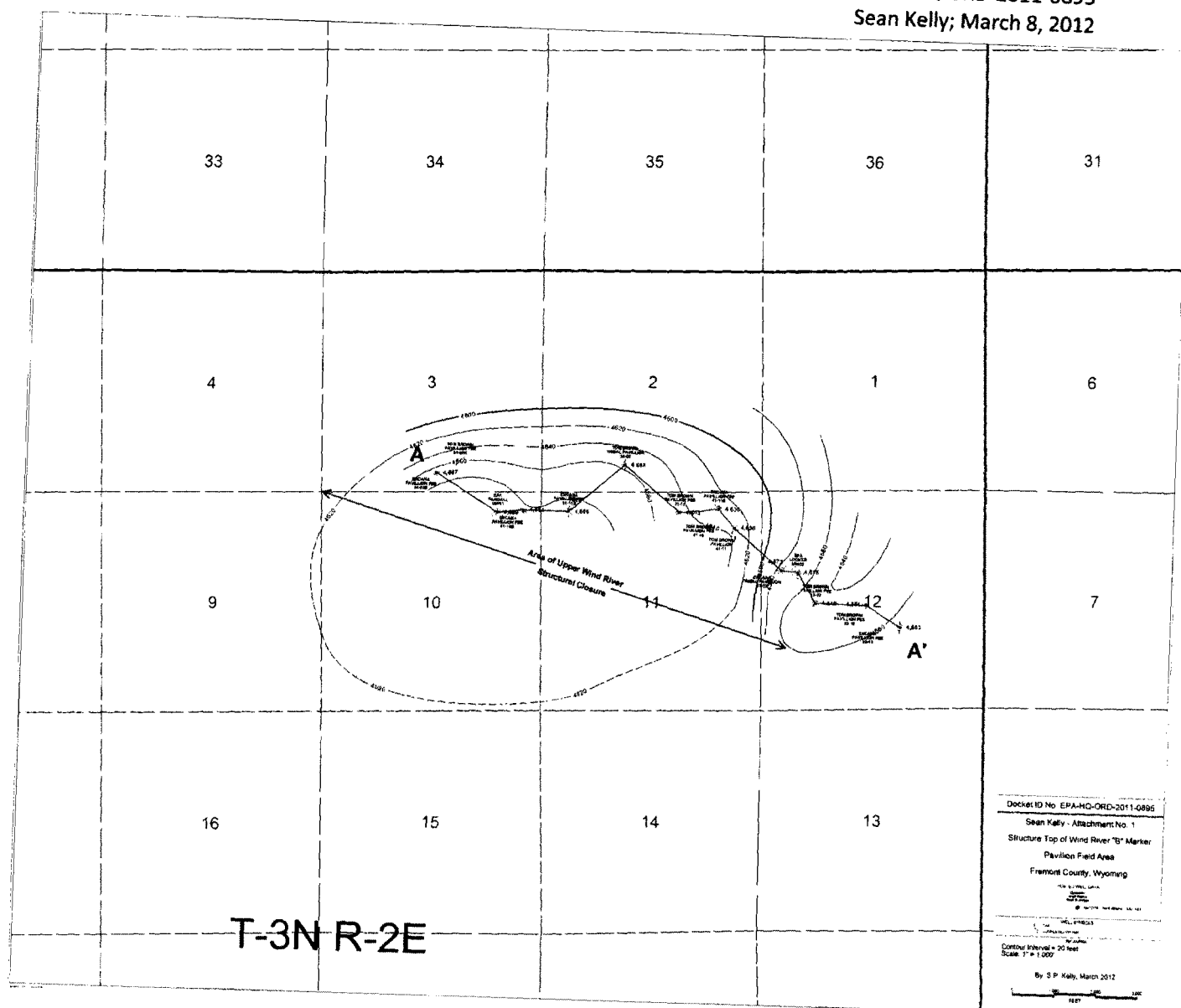
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**Attachments:** Full size versions of **Sean Kelly-Attachments No. 1-3** have are included with my comment.

**Attachment No. 1** is a map showing the location of the wells I have evaluated in reviewing the Draft Report. Each well is identified by operator, well name and well number. Posted at each well location in red is the elevation of the informally named Wind River "B" Marker. Structural contours at a 20' contour interval are based on the elevation of the top of the informally named Wind River "B" Marker. The location of west to east cross section A – A' is shown in blue.

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**Attachment No. 1** Base map showing wells evaluated and structure top of Wind River Formation "B" Marker.

**Attachment No. 2** is stratigraphic correlation cross section A – A' which uses the informally named Wind River "B" Marker as a datum. This cross section is used to make well to well correlations defining the stratigraphy of the upper Wind River Formation.

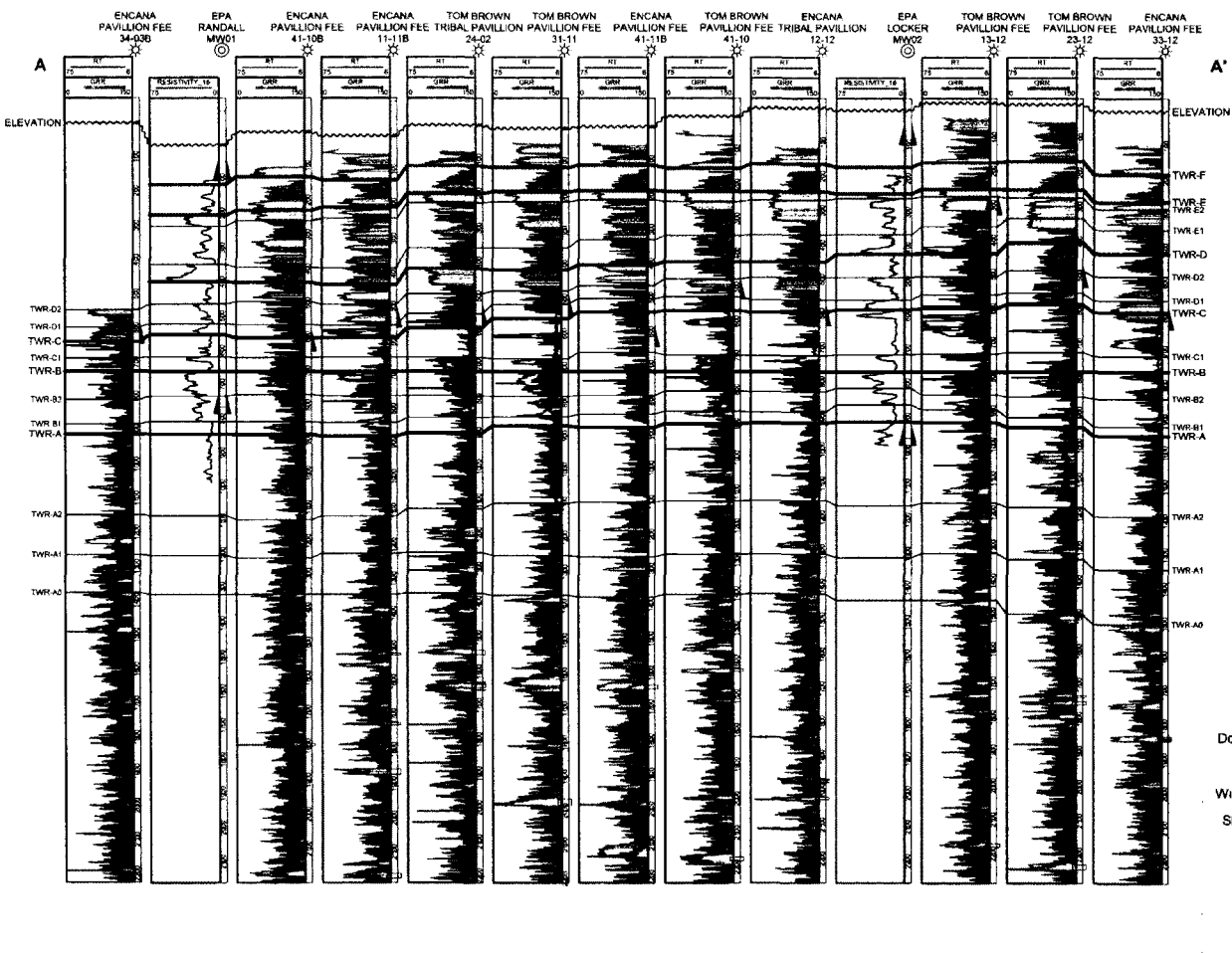
Cross section wells are identified by operator, well name and well number posted above the well symbol. Depth in feet below the reference elevation is shown in the depth track. The depth scale is 1" = 200' and the wells are evenly spaced with no horizontal scale. Casing shoe points are indicated by black triangles, and perforated intervals are indicated by pink squares in the depth tracks. The screened intervals in the two EPA monitor wells are also indicated by pink squares in the depth tracks.

Resistivity curves are plotted in track 1 for each well on a linear scale of 75 to 0 ohm-m in a solid red curve. Gamma ray curves are also plotted in track 1 for each well with an available gamma ray log on a linear scale of 0 to 150 API units in a solid black curve. Where the gamma ray was run in a cased hole portion of the well, the data has been normalized so that 95% of the gamma ray data is greater than 45 API units and 5% of the gamma ray data is greater than 130 API units. The resistivity curves show good correlation to the gamma ray curves when plotted at these scales which provides confidence for correlating the resistivity curves provided for the two deep monitor wells to the logs from the producing gas wells in the area.

The gamma ray curve is shaded based on gamma ray values. Sandstone intervals are generally shaded from yellow to orange, and shale intervals are generally shaded from gray to black.

The correlations of the informally named Wind River stratigraphic tops are shown in red and green lines. Overall, there is good correlation of the upper Wind River stratigraphy along the span of cross section A – A'.

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**Attachment No. 2** stratigraphic correlation cross section A – A'. Datum Wind River Formation "B" Marker.

**Attachment No. 3** is structural cross section A – A' which utilizes a "triple-combo" log display. Cross section wells are identified by operator, well name and well number posted above the well symbol. Depth in feet below the reference elevation is shown in the depth track. The depth scale is 1" = 100' and the horizontal scale is 1" = 225'. Casing shoe depths are indicated by black triangles, and perforated intervals are indicated by pink squares in the depth track. The screened intervals in the two EPA monitor wells are also indicated by pink squares in the depth tracks.

The correlations of the informally named Wind River stratigraphic tops are shown in red and green lines, and are identical to the correlations shown in **Attachment No. 2**.

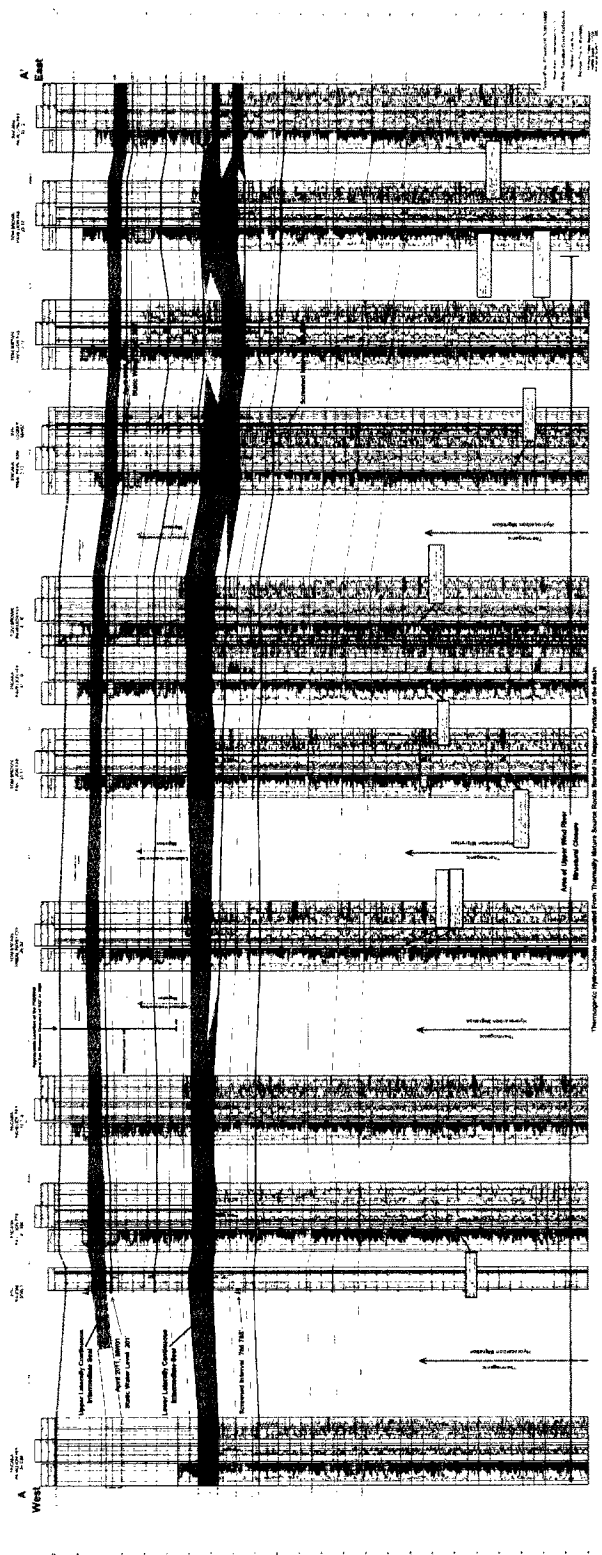
Gamma ray curves are plotted in track 1 for each well with an available gamma ray on a linear scale of 0 to 150 API units as a solid black curve. Where the gamma ray was run in a cased hole portion of the well, the data has been normalized so that 95% of the gamma ray data is greater than 45 API units and 5% of the gamma ray data is greater than 130 API units. The gamma ray curve is shaded based on gamma ray values. Sandstone intervals are generally shaded from yellow to orange, and shale intervals are generally shaded from gray to black.

A caliper log is also plotted in track 1 for each well with an available caliper on a linear scale of 4 to 14 inches as a solid black curve.

Resistivity curves are plotted in track 2 on a log scale of 2.0 to 200 ohm-m. The shallow resistivity curve is plotted as a black dotted curve, the medium resistivity curve is plotted as a black dashed curve and the deep resistivity is plotted as a solid red curve. Where the deep resistivity reading is greater than a 20 ohm-m it is shaded green.

Porosity curves are plotted in track 3 for each well with an available porosity log on a linear scale of 30% to 0%. Density porosity is plotted as a solid red curve, and neutron porosity is plotted as a black dashed curve. Density porosity is calculated using an assumed matrix density of 2.65 g/cc. Where the neutron porosity reads less than the density porosity (a condition known as "cross-over" or "gas effect") the cross-over is shaded red with a black stippled pattern.

Wind River Formation intervals which have been proven productive of natural gas through perforating and testing in gas productive wells are consistently identified by open hole log responses where the deep resistivity is greater than 20 ohm-m and the neutron-density porosity exhibits crossover or gas effect. All intervals which have these "natural gas pay parameters" of combined deep resistivity greater than 20 ohm-m and neutron-density crossover are highlighted by red shading between the neutron porosity curve and the right edge of track 3.



**Attachment No. 3** is structural cross section A – A' which utilizes a “triple-combo” log display.